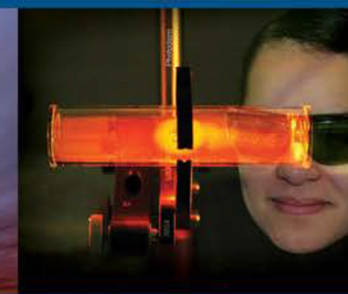
AIR FORCE RESEARCH LABORATORY

TECHNOLOGY MILESTONES



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INTRODUCTION: Click any colored section title to jump directly to that particular section in the book.

TABLE OF CONTENTS (TOC): Click any title listed in the TOC to navigate immediately to the selected story.

AFRL TECHNOLOGIES: Click the name of any Technology Directorate (TD) to open a new window containing the AFRL Web site for that TD.

FOOTER: To e-mail the point of contact for a particular milestone, click the address located in the footer for the item of interest.

Technology Milestones can be reviewed at http://www.wpafb.af.mil/news/index.asp?catid=163.
To receive more information about AFRL, visit the home page at www.wpafb.af.mil/afrl.

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AFRL's Mission: Creating the Future

The Air Force Research Laboratory (AFRL) is the science and technology arm of the Air Force, supplying vast and unparalleled service in air, space, and cyber domains. AFRL's support of the warfighter is reflected in its enterprise-wide commitment to the future—game-changing technologies in all realms—and its laserlike focus on details that alter the face of battle. This one entity—AFRL—is in truth thousands of scientists and engineers whose work, while disparate, is unified in a dedication to the influential science and technology that positions the Air Force at the forefront of innovation.

AFRL Technology Milestones Program

The *AFRL Technology Milestones* program chronicles these endeavors and spotlights their significance on several fronts: addressing urgent warfighter needs, pursuing discovery, and transitioning results when other military or commercial interest warrants.

AFRL's workforce (comprising more than 1,300 military; 5,200 civilian; and 4,300 on-site contractor personnel) is, on any given day, concentrating on technologies as diverse as insect-sized micro air vehicles, algae-based biofuels, aircrew comfort, and holographic optics. Diversity does not end there; the lab's dedication to workplace diversity is highlighted in the Diversity section, emphasizing the importance placed on this facet of technological achievement.

In documenting AFRL's dedication to Air Force operational preeminence, these *Technology Milestones* summarize the lab's research and development contributions that commenced, concluded, or gained steady progress in 2010. Viewed individually, the stories provide snapshots of AFRL's myriad science and technology activities. Collectively, they paint a portrait of a lab strong in talent, long on vision, and resolute in mission.

For more information on any milestone contained within this publication, please visit the AFRL Technology Milestones program Web site, located at **www.wpafb.af.mil/news/index.asp?catid=163**.

Ellen M. Pawlikowski

ELLEN M. PAWLIKOWSKI
Major General, USAF
Commander

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TECH TRANSITION/TRANSFER

AWARDS & RECOGNITION

DIVERSITY

INTRODUCTION

Introduction

The Air Force Science and Technology Milestones assembled in this book often represent the combined effort of several scientists and engineers, or groups thereof, working as a team. The basic research, applied research, and follow-on technology development efforts described herein are essential to the continued success of the Air Force mission. This book is a compilation of notable Technology Milestones selected from the following categories.

Response to Needs

Technology that demonstrates potential for, or has already achieved, application on a developmental or operational Department of Defense (DoD) system and/or technology that provides "quick-reaction" response to problems or needs of field organizations

Discovery

Major innovative technological advancements that offer significant potential for existing and future Air Force systems

Tech Transition/Transfer

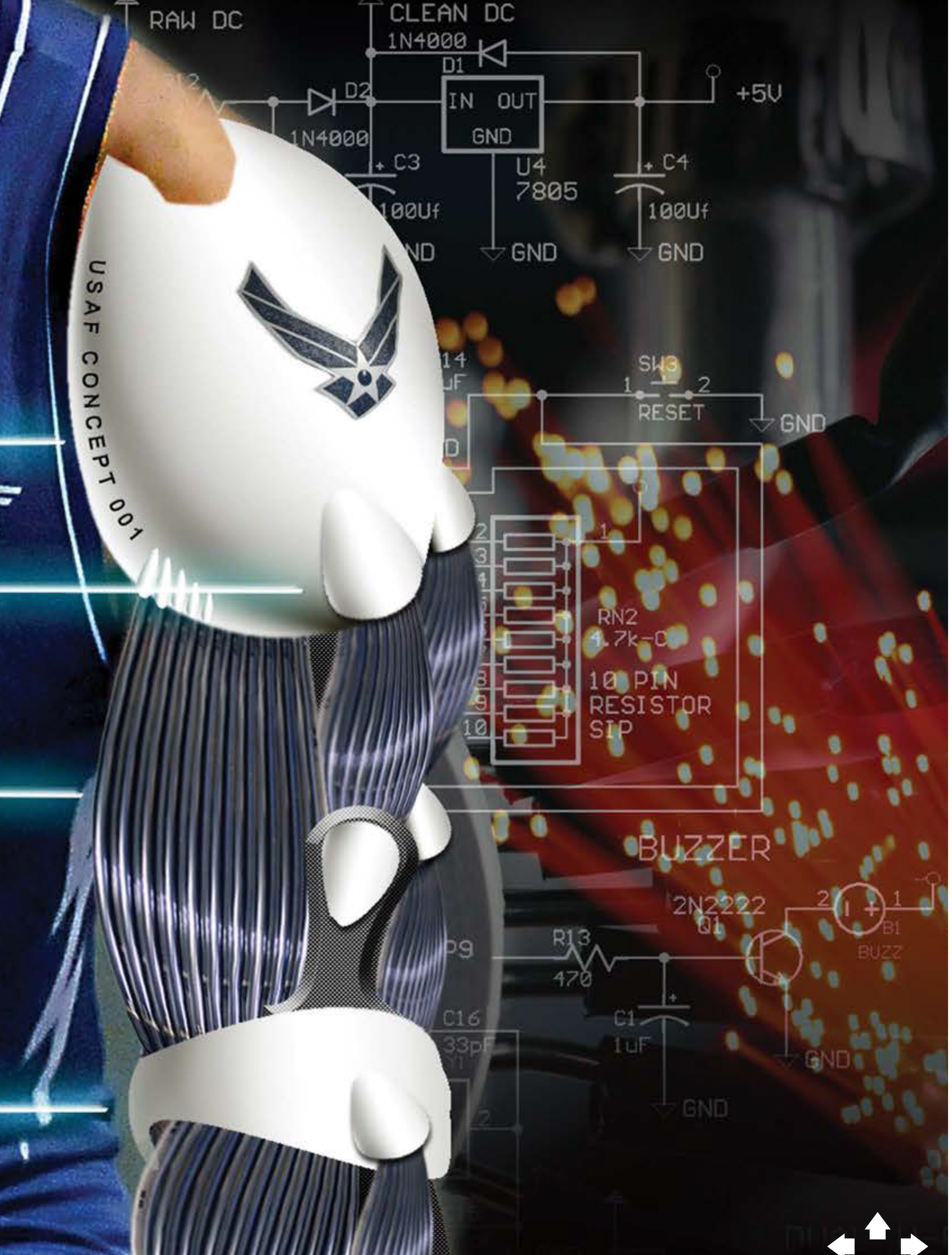
Technology that has transferred from the laboratory to the private sector, to include industry, academia, and state and local governments

Awards and Recognition

Acknowledgment of AFRL contributions within the science and engineering community at large, concerning technology advancements in the areas of technology transition, technology transfer, or technical achievement

Diversity

Significant partnerships and activities with academia, including K-12 and college/university faculty and students (undergraduate through postdoctoral); nonprofit organizations; other DoD agencies; and/or industry



AFRL Technologies

Air Force Office of Scientific Research (AFOSR)

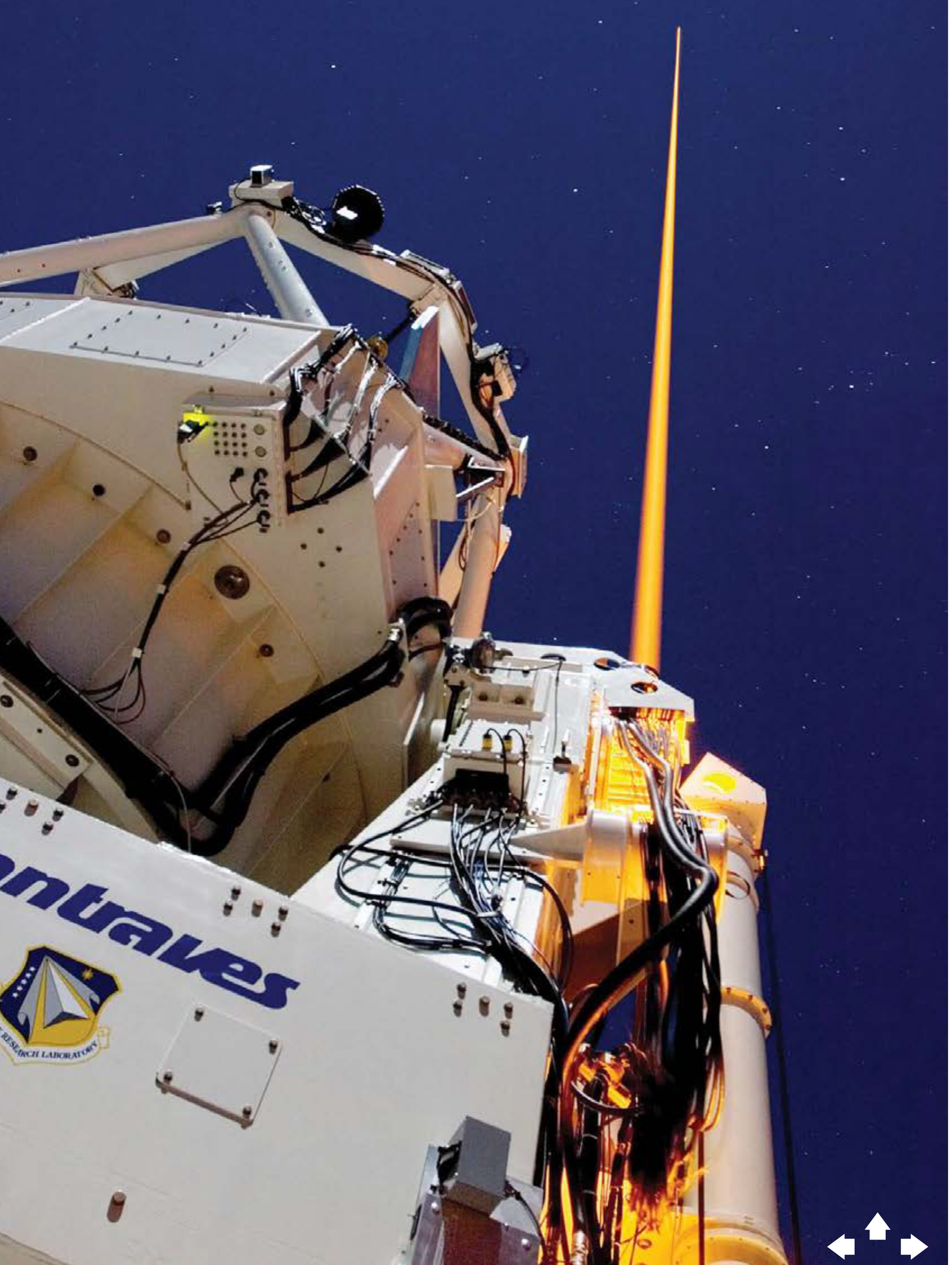
Mission Statement: As a vital component of AFRL, AFOSR's mission is to support Air Force goals of control and maximum utilization of air, space, and cyberspace. AFOSR accomplishes its mission by investing in basic research efforts that support the Air Force mission in relevant scientific areas. Central to AFOSR's strategy is the identification of long-range technology options for national defense, as well as the timely transfer of related scientific knowledge to industry, the academic community, and government laboratories that foster developmental research leading to revolutionary technologies for the Air Force.

- Aerospace, Chemical, and Material Sciences
  - Mechanics of Multifunctional Materials and Microsystems
  - Surface and Interfacial Science
  - Organic Materials Chemistry
  - Molecular Dynamics
  - Theoretical Chemistry
  - Molecular Design and Synthesis
  - High-Temperature Aerospace Materials
  - Low-Density Materials
  - Hypersonics and Turbulence
  - Flow Control and Aeroelasticity
  - Space Power and Propulsion
  - Combustion and Diagnostics
  - Multiscale Structural Mechanics and Prognosis
- Physics and Electronics
  - Atomic and Molecular Physics
  - Information Processing and Storage
  - Multiscale Modeling
  - Plasma and Electro-Energetic Physics
  - Electromagnetics
  - Laser and Optical Physics
  - Remote Sensing and Imaging Physics
  - Space Sciences
  - Quantum Electronic Solids
  - Adaptive Multimode Sensing and Ultra-High-Speed Electronics
  - Optoelectronics: Components, Integration, and Information Processing and Storage
  - Sensing, Surveillance, and Navigation
  - Mathematics, Information, and Life Sciences
  - Complex Networks
  - Bioenergy
  - Robust Computational Intelligence
  - Systems and Software
  - Information Operations and Security
  - Sensory Information Systems
  - Computational Mathematics
  - Information Fusion
  - Dynamics and Control
  - Mathematical Modeling of Cognition and Decision
  - Natural Materials and Systems
  - Optimization and Discrete Mathematics
  - Collective Behavioral and Socio-Cultural Modeling

Air Vehicles Directorate

Mission Statement: The Air Vehicles Directorate plans, formulates, and directs US science and technology development (research, exploratory, and advanced) for military air vehicles; orchestrates and executes technology developments in aeronautical/control sciences and aerospace structures; integrates air vehicle technologies across all AFRL technology directorates at the systems level; and orchestrates this technology development with Department of Defense and national labs, industry and academia, the National Aeronautics and Space Administration and Federal Aviation Administration, the North Atlantic Treaty Organization, and other foreign research agencies.

- Propulsion Integration
- Weapons Integration
- Experimental Aeronautical Sciences
- Flow Control/Flow Physics
- Plasma Physics
- Low-Speed Aerodynamic Configurations
- High-Speed Aerodynamic Configurations
- Multidisciplinary Computational Research
- High-Speed Computational Research
- Applied Computational Science
- Control Systems and Theory
- Unmanned Air Vehicle Cooperative Control
- Space Access and Hypersonics Guidance and Control
- Flow Control, Mechanization, and Automation
- Simulation-Based Research and Development
- Multifunctional Structures
- Hybrid Structures
- Composite Structures
- Metallic Structures
- Thermal Structures
- Adaptive Structures
- Structural Health Assessment
- Computational/Analytical Certification
- Combined Environments (Structures)
- Multidisciplinary Design and Demonstration
- Aeroelasticity Analysis Methods
- Structural Integrity
- Structural Dynamics
- Experimental Structures
- Air-Space Operations
- Photonic Flight Control
- Adaptive Control
- Software Verification and Validation
- Systems Engineering "Lite"
- Thermal Systems



Directed Energy Directorate

Mission Statement: The Directed Energy Directorate leads the discovery, development, and delivery of directed energy science and technology for national security.

- High-Energy Lasers:
  - Midinfrared Semiconductor Lasers
  - Fiber Lasers
  - High-Power Gas Lasers
  - Solid State Thin-Disk Lasers
- High-Power Microwaves:
  - Low-Frequency Microwaves
  - High-Frequency Microwaves
  - Pulsed Power
  - High-Energy-Density Plasmas
- Beam Control:
  - Atmospheric Propagation-Adaptive Optics
  - Acquisition, Tracking, and Pointing
  - Space Situational Awareness
- Modeling, Simulation, and Effects:
  - Effects
  - Physics
  - Systems
  - Mission

711th Human Performance Wing (711 HPW)

Mission Statement: The 711 HPW advances human performance in air, space, and cyberspace through research, education, and consultation.

The 711 HPW merges the AFRL Human Effectiveness Directorate with the mission organizations of the 311th Human Systems Wing currently located at Brooks City-Base, Texas, the Human Performance Integration Directorate, and the United States Air Force School of Aerospace Medicine.

- 3-D Audio
- Anticipate and Influence Behavior
- Aircrew Performance and Protection
- Applied Biotechnology
- Battlespace Acoustics and Visualization
- Behavior Modeling
- Biobehavioral Systems
- Biomechanics
- Biosciences and Protection
- Biotechnology
- Chemical-Biological Agent Defense
- Cognitive Interface Technologies
- Cognitive Modeling
- Collaborative Interfaces
- Competency-Based Performance Measurement and Tracking
- Continuous Learning and Learning Management Technologies
- Counterproliferation
- Cultural Behavior Modeling and Representation
- Cyberspace
- Directed Energy Bioeffects
- Distributed Mission Operations Training Research
- Fatigue Countermeasures
- Human-Centered Logistics Research
- Human-System Interface Design
- Immersive Training/Rehearsal Simulation Environments
- Information Operations and Applied Mathematics
- Laser Eye Protection
- Live-Virtual-Constructive Integration
- Logistics Readiness
- Maintenance Job Aiding
- Nanotechnology
- Night-Vision, Helmet-Mounted, and Large-Screen Displays
- Nonlethal Technologies
- Operations Support
- Optical Radiation Bioeffects
- Radio Frequency Radiation Bioeffects
- Sensemaking and Organizational Effectiveness
- Situational Awareness
- Space
- Speech-Recognition Technologies
- Toxicology
- Veterinary Sciences
- Warfighter Readiness Research
- Warfighter/Weapons Systems Integration

Information Directorate

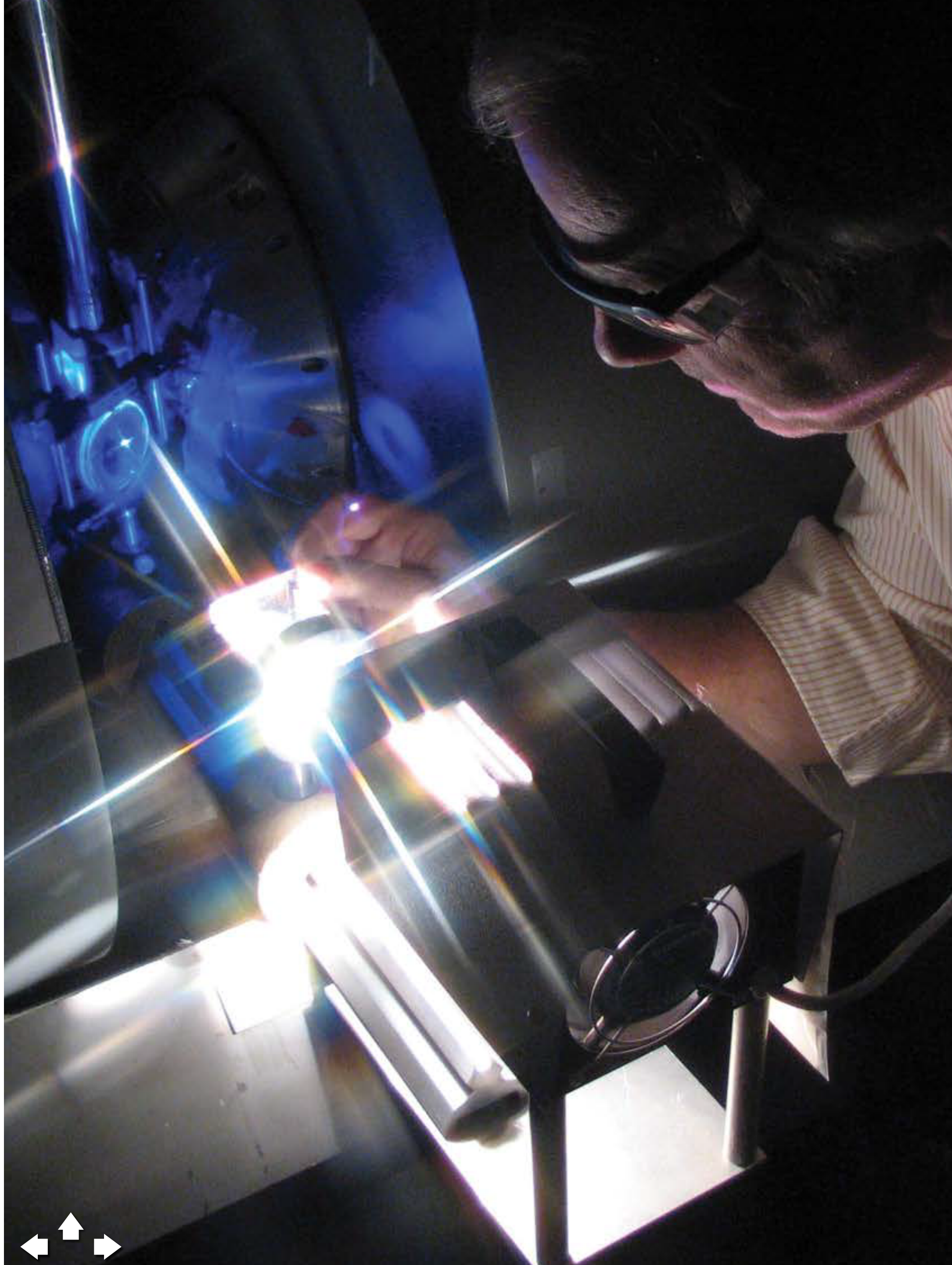
Mission Statement: The Information Directorate leads the discovery, development, and integration of affordable warfighting information technologies for the nation's air, space, and cyberspace forces.

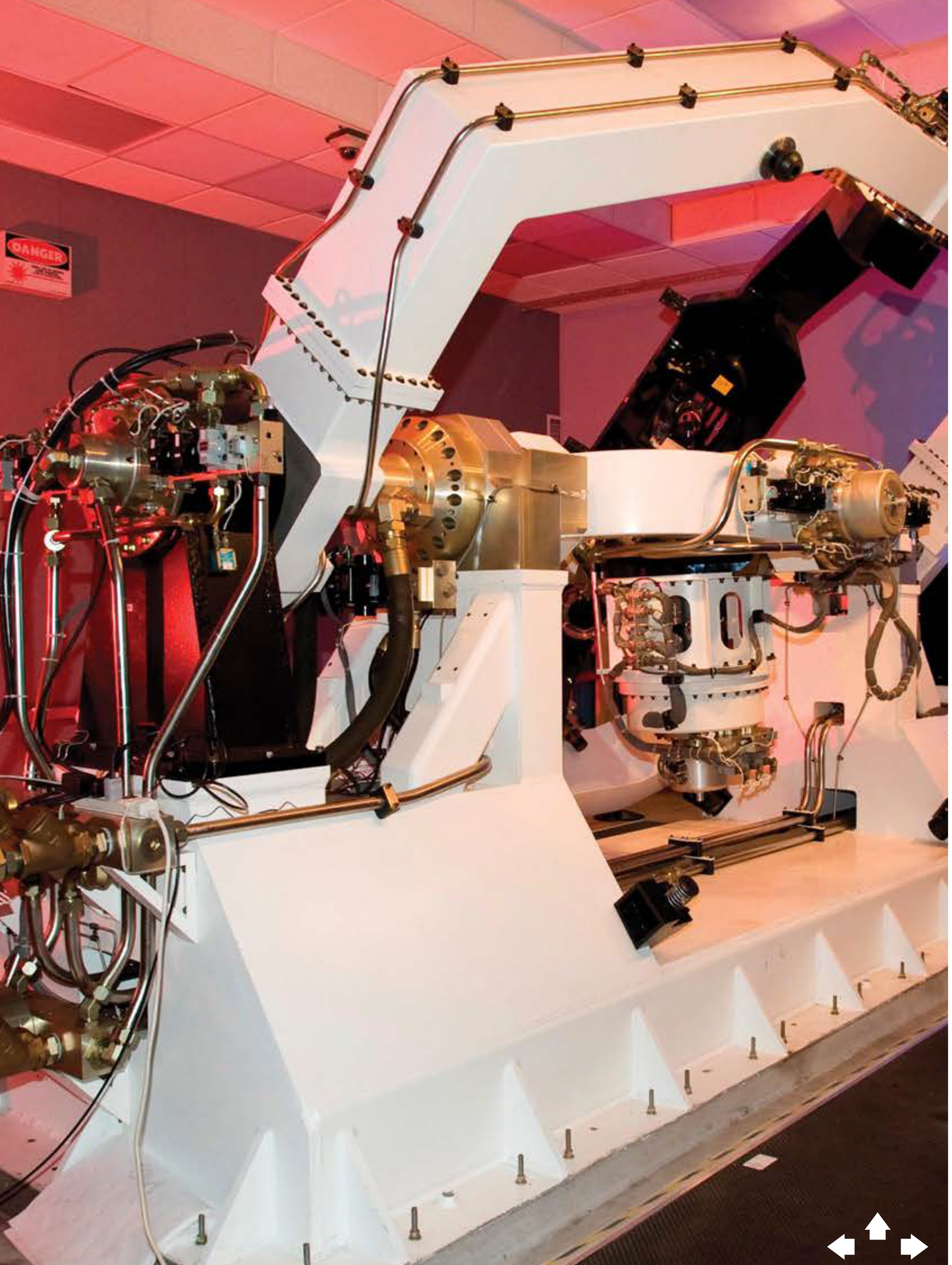
- Information Dominance (ground, air, and space systems)
- Information Exploitation
- Information Fusion
- Communications and Networking
- Information Management
- Advanced Computing Architectures
- Information Exploitation
- Information Fusion
- Information Understanding
- Signal Processing
- High-Performance and Adaptive Computing
- Collaborative Environments
- Advanced Displays and Intelligent Interfaces
- Modeling and Simulation
- Information Assurance
- Intelligent Information Systems (including intelligent agents, planning/scheduling and decision aids, knowledge bases, and access)
- Analytics
- Cyber Resilience
- Neuromorphic Computing
- Trusted Computing Architectures
- SA across Air, Space, and Cyberspace
- Cyber Agility
- Resilient Cyber Systems
- Trusted Hardware and Software
- Mission-Focused Autonomy
- Contested Environments
- Quantum Computing
- Decision making technologies

Materials and Manufacturing Directorate

Mission Statement: The Materials and Manufacturing Directorate plans and executes the US Air Force program for materials and manufacturing in the areas of basic research, exploratory development, advanced development, and industrial preparedness and also provides responsive support to Air Force product centers, logistics centers, and operating commands in order to solve systems- and deployment-related problems and transfer expertise.

- Accelerated Insertion Materials
- Advanced Composite Processing and Behavior
- Advanced Industrial Practices
- Advanced Inspection
- Advanced Metallics
- Airbase Infrastructure
- Aircraft and Spacecraft Coatings
- Amorphous Metals
- Analytical Chemistry Research
- Materials Biotechnology
- Ceramics and Ceramic Matrix Composites
- Composites Supportability
- Computational Chemistry
- Corrosion Control
- Electronics
- Electrostatic Discharge Research
- Engine Rotor Life Extension
- Environmental Technologies
- Firefighting Technology
- Force Protection Research
- Hardened Materials
- High-Cycle Fatigue
- High-Resolution Flaw/Feature Imaging
- Infrared Sensors and Transparencies
- Laser-Hardened Materials
- Magnetic Materials Processing
- Manufacturing and Engineering Systems
- Manufacturing Processing and Fabrication
- Materials Affordability Initiatives
- Materials Behavior and Evaluation
- Materials Life Prediction and Durability
- Materials Process Design
- Materials Supportability
- Metallic Composites
- Metal Matrix Composites
- Metals Processing
- Nanotechnology
- Nondestructive Evaluation
- Nonmetallic Composite Materials
- Optical and Photonic Materials
- Organic Matrix Composites
- Pollution Prevention Materials
- Polymeric Materials
- Power and Chemical Processes
- Quantitative Defect Characterization
- Robotics Research
- Semiconductor Materials
- Sensor Technologies
- Structural and Electronic Failure Analysis
- Superlattice and Quantum-Well Materials
- Surface Phenomena/Interactions
- Systems Support
- Thermal Protection Materials
- Wide-Bandgap Materials
- Dielectric Materials
- Energy Generation and Storage
- Liquid Crystal Materials
- Metamaterials
- Thermal Materials Science
- Taggants
- Hybrids
- Integrated Computational Materials Science and Engineering





Munitions Directorate

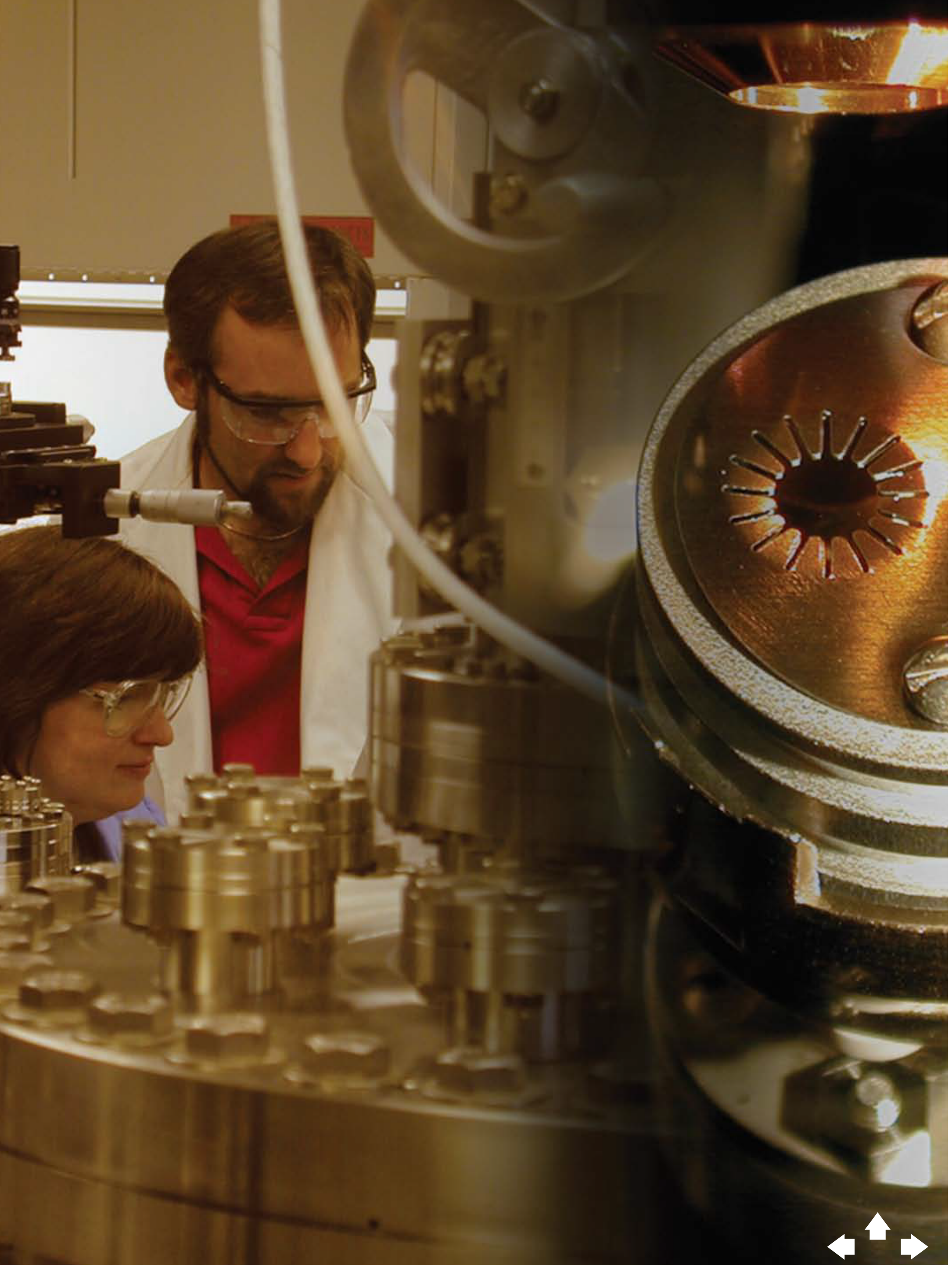
Mission Statement: The Munitions Directorate leads the discovery, development, integration, and transition of affordable precision engagement technologies for our air, space, and cyberspace forces. Ordnance (warheads, fuzes, and explosives)

- Munitions Energetic Materials:
  - Energetic Material Formulation
  - Energetic Material Processing
  - Computational Energetics
  - Energetic Material Characterization and Phenomenology
- Damage Mechanisms Science:
  - Material Science
  - Computational Multiphase Flow
  - Computational Solid Mechanics
  - Energy Conversion
  - Energy Coupling
  - Nontraditional Defeat Mechanisms
  - Fuze Technology:
- Fuze Energetic Initiation Science and Technology:
  - Hard Target Defeat Fuzing Technology
  - High-G Shock and Vibration Simulation and Modeling
  - Feature Extraction for Fuze Aimpoint Detection and Selection
  - Fuze End-Game Sensing Technology
- Terminal Seeker Sciences:
  - Target Reacquisition and Recognition Theory
  - Radio Frequency (RF) Seekers
  - Electro-Optic (EO)/Infrared (IR) Seekers
  - Bio-Inspired, Multispectral, Multiaperture Seekers
- Munitions Aerodynamics, Guidance, Navigation, and Control:
  - Navigation
  - Control
  - Guidance and Avionics
  - Munitions Aerodynamics Sciences
- Munition System Effects Sciences:
  - Weapon-Target Interaction
  - Virtual Environment Simulation
  - Physical Effects Simulators/Stimulators
  - Applied Munitions System Simulation Sciences
  - Seekers and Guidance
  - Navigation
  - Control Algorithms
  - Airframe
  - Inertial sensors
  - Fuzes
  - Warhead and Explosive
- Critical Technical Functions:
  - Propulsion
  - Data Link
  - Power
  - Carriage and Release
  - Human-in-the-Loop
  - Gun Caliber Expertise

Propulsion Directorate

Mission Statement: The Propulsion Directorate plans and executes the Air Force's basic research, exploratory development, and advanced development programs for flight vehicle propulsion and power technology; conducts in-house research and development to exploit new opportunities, maintain technical expertise, and verify contractor findings; provides technical and management assistance in support of studies, analyses, development planning activities, acquisition, test, evaluation, modification, and operation of air, space, and weapons systems and related equipment; provides the principal Air Force interface with scientific, industrial, educational, and other government agencies; and serves as the Air Force Materiel Command focal point in these technical areas.

- Turbine Engines
- Rocket Engine Test Facilities
- Turbine Engine Augmentors
- Solid-Fueled Ramjets
- Turbine Engine Bearings
- Solid Propellants
- Combined-Cycle Engines
- Solid Rocket Boosters
- Subsonic and Supersonic Combustion
- Solid Rocket Service Life
- Compressors
- Solid Rocket Motors
- Turbine Engine Controls
- Carbon Fibers and Composites
- Turbine Engine Diagnostics
- Ceramic Processing
- Endothermic Fuels
- Computational Chemistry
- Engine Starting Systems
- Electric Propulsion
- Engine Health Monitoring Systems
- High-Energy-Density Matter
- Exhaust Nozzles
- Injectors and Spray Measurements
- Fans
- Laser Propulsion
- Fuel Pumps and Fuel Systems
- Liquid Rockets and Combustion
- Gas Generators
- Micropropulsion
- Gears
- Monopropellants
- High-Cycle Fatigue (and its mitigation)
- Nontoxic Propellants
- Ignition Prognostics
- Plume Phenomenology
- Lubrication Systems
- Power Conditioning Equipment
- Oil Specifications, Diagnostics, and Analysis
- Propulsion Fluid Dynamics
- Oil Monitors
- Rocket Materials
- Optical Diagnostics
- Rocket-Based Combined-Cycle Engines
- Pressure-Sensitive Paints
- Solar Propulsion
- Pulsed-Detonation Engines
- Thermal Management
- Scramjets (supersonic combustion ramjets)
- Thermionics
- Seals
- Auxiliary Power Units
- Turboramjets



- Batteries and Fuel Cells
- Turboshaft Engines
- Capacitors
- Very Short Takeoff and Landing Propulsion
- Circuit Breakers
- Air Turborockets
- Converters/Inverters
- Hybrid Rockets
- Electric Motors
- Intercontinental Ballistic Missile Propulsion
- Conventional and Superconducting
- Liquid-Fueled Ramjets
- Generators

Sensors Directorate

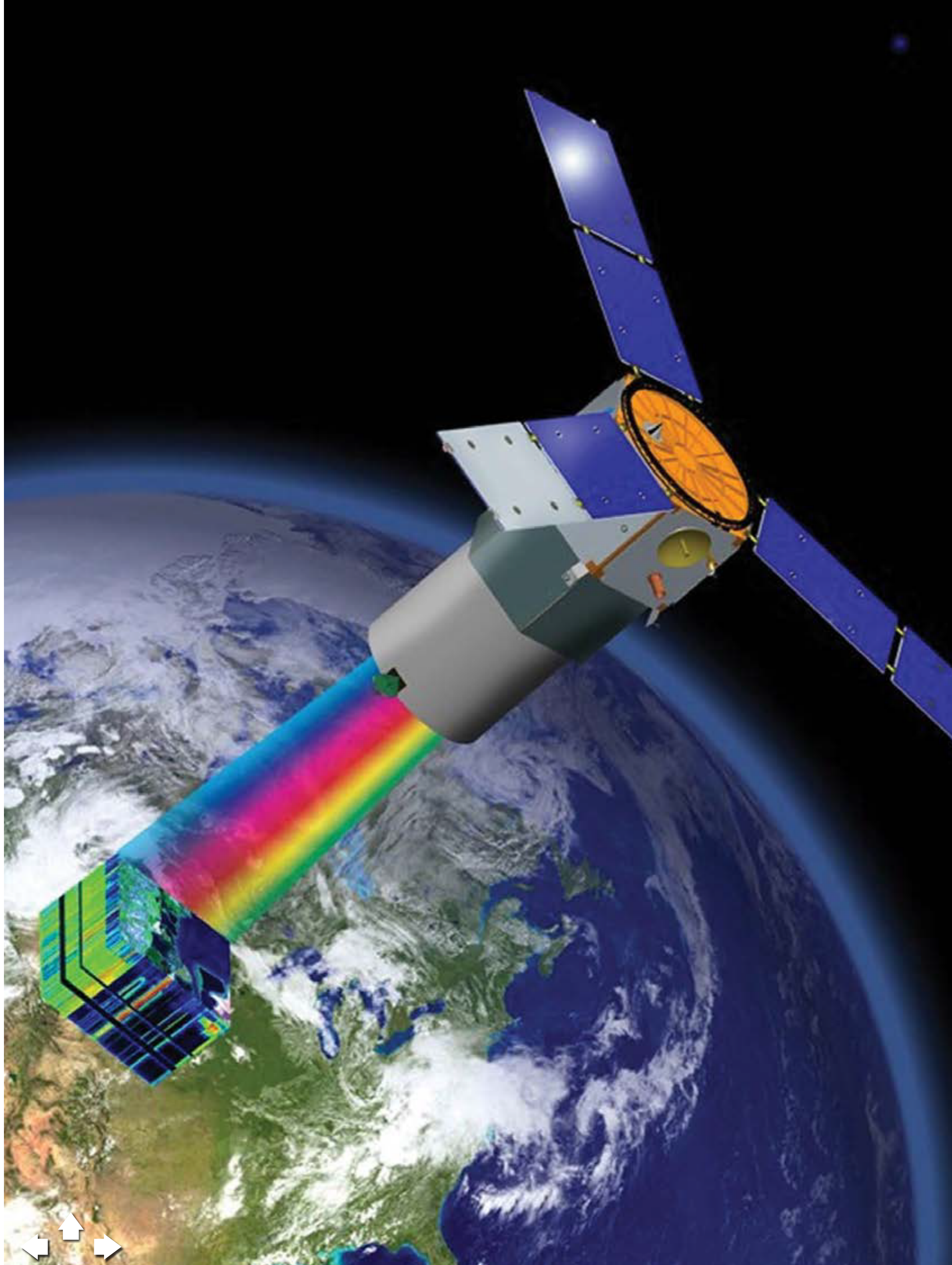
Mission Statement: The Sensors Directorate leads the discovery, development, and integration of affordable sensor and countermeasure technologies for warfighters.

- Radio Frequency (RF) Sensing
- Electro-Optical (EO) Sensing
- Net-Centric Spectrum Warfare
- EO Electronic Warfare
- Layered Sensing Exploitation
- Enabling Sensor Devices/Components

Space Vehicles Directorate

Mission Statement: The Space Vehicles Directorate develops and transitions innovative high-payoff space technologies supporting the warfighter, while leveraging commercial, civil, and other government space capabilities to ensure America's advantage.

- Aerospace Environment Warfighting Systems
- Revolutionary Space Capabilities for Global Awareness
- Vital Developing Military Space Concepts



RESPONSE TO NEEDS

Riding the Wave of Scramjet-Powered Hypersonic Flight

The initial launch of AFRL's X-51A Waverider flight test vehicle broke aviation records as the longest-ever supersonic combustion ramjet (scramjet)-powered hypersonic flight. The event—an unqualified success culminating 6 years of collaborative effort between AFRL, the Defense Advanced Research Projects Agency, and industry—entailed a 200+ sec burn by the engine, an air-breathing scramjet that accelerated the vehicle to Mach 4.8, or nearly 4,000 mph. Before this milestone achievement, which marks the first use of a practical hydrocarbon-fueled scramjet in flight, the longest scramjet burn achieved in a flight test was the National Aeronautics and Space Administration X-43 vehicle's 12 sec run.

Normally defined as Mach 5 and beyond, hypersonic flight presents unique technical challenges related to heat and pressure. These extremes render conventional turbines impractical; they also pose problems in producing thrust via scramjet—problems akin to lighting a match in a hurricane and keeping it burning. To overcome these issues, Pratt & Whitney Rocketdyne worked with Boeing Phantom Works to incorporate a fuel-cooled engine design. The design serves both to heat the JP-7 fuel to optimal combustion temperature and to assist the engine in enduring the extremely high operating temperatures of long burns. In addition to demonstrating scalable scramjet propulsion, the X-51A configuration validates thermal protection system materials, airframe and engine integration, and high-speed stability and control.

The flight of AFRL's remaining three industry-built Waveriders will occur based on data review results and available funding. To control costs, the team has leveraged proven technologies wherever possible and will continue to do so. Likewise, the Air Force intends to employ virtually identical flight profiles for the trio of future launches, building knowledge with each successive flight. The ample data collected by onboard sensors for this flight test alone—between 140 and 170 seconds' worth—will play a cumulative role in transforming a breakthrough propulsion technology into actual warfighting capability. Rapid engagement of long-distance targets, coupled with a capacity to capture and burn oxygen in the thin atmosphere (eliminating the need for oxidizer tanks such as those carried by the space shuttle and other rockets) are just two of the new scramjet engine's distinct advantages.

In demonstrating the technology's viability for propelling an aerospace vehicle, the success of this effort greatly increases the likelihood that more Waverider vehicles will be built and, further, that the engine technology itself will ultimately contribute to the creation of game-changing space access and hypersonic weapons platforms.

AFRL's X-51A Waverider completed its first scramjet-powered hypersonic flight after launching aboard a B-52 from Edwards Air Force Base, California.

Pictured (top) is the use of a high-energy laser (aboard MATRIX) as it negates a UAS. Pictured (bottom) to right are AFRL counter UAS demonstration participants Second Lieutenant Kyle Dufaud, 2Lt Shon Neal, and Mr. Nick Tarasenko as they observe a UAS crash site.

AFRL "MATRIXed" to Counter UAS Demonstration Activities

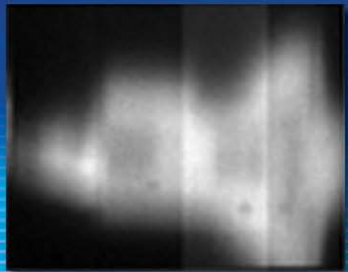
AFRL participated in a counter unmanned aerial system (UAS) demonstration conducted at the Naval Air Weapons Station, China Lake, California. The event showcased the lab's capacity for using laser technologies to deny UAS mission success from mobile platforms. Using a high-energy laser on the Mobile Active Targeting Resource for Integrated eXperiments (MATRIX), AFRL participants successfully acquired, tracked, and negated five of five UASs at tactically significant ranges. Participants employed a second system, the Mobile Acquisition and Tracking System, to demonstrate additional technologies for passive acquisition and tracking of small UASs, as well as laser engagement.

The annual demonstration event serves to improve US capability in preventing, detecting, tracking, and engaging hostile homeland and theater air threats. It provides a venue for obtaining information on commercially available, improvised, and/or state-sponsored small UASs that pose a potential threat to soft targets. The primary goal is to assess the nature of these current systems in the context of various research capabilities devised for defeating them.

New Focus on Space Object Identification

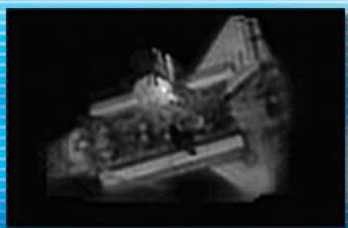
A just-released AFRL software update will significantly aid the identification of space objects. Improvements to Physically Constrained Iterative Deconvolution (PCID) software promise image processing results at resolutions considerably higher than previous products were able to provide. A primary function of PCID involves its capacity to remove the substantial atmospheric blurring that frequently impacts telescopic observation of space objects. This processing enhancement will, in turn, assist scientists in determining details associated with spacecraft configuration, mission, and status.

The upgraded PCID software also exhibits dramatically decreased run times, achieved via supercomputing, software engineering, and optimization. Specifically, the software now processes imagery at speeds 20 times faster than those attainable 2 years ago, and 300 times faster than the original code could achieve. Based on its newly advanced role in space object identification, the PCID software has undergone transition for image analyst use in providing US Strategic Command and other organizations with a wealth of valuable space object information.



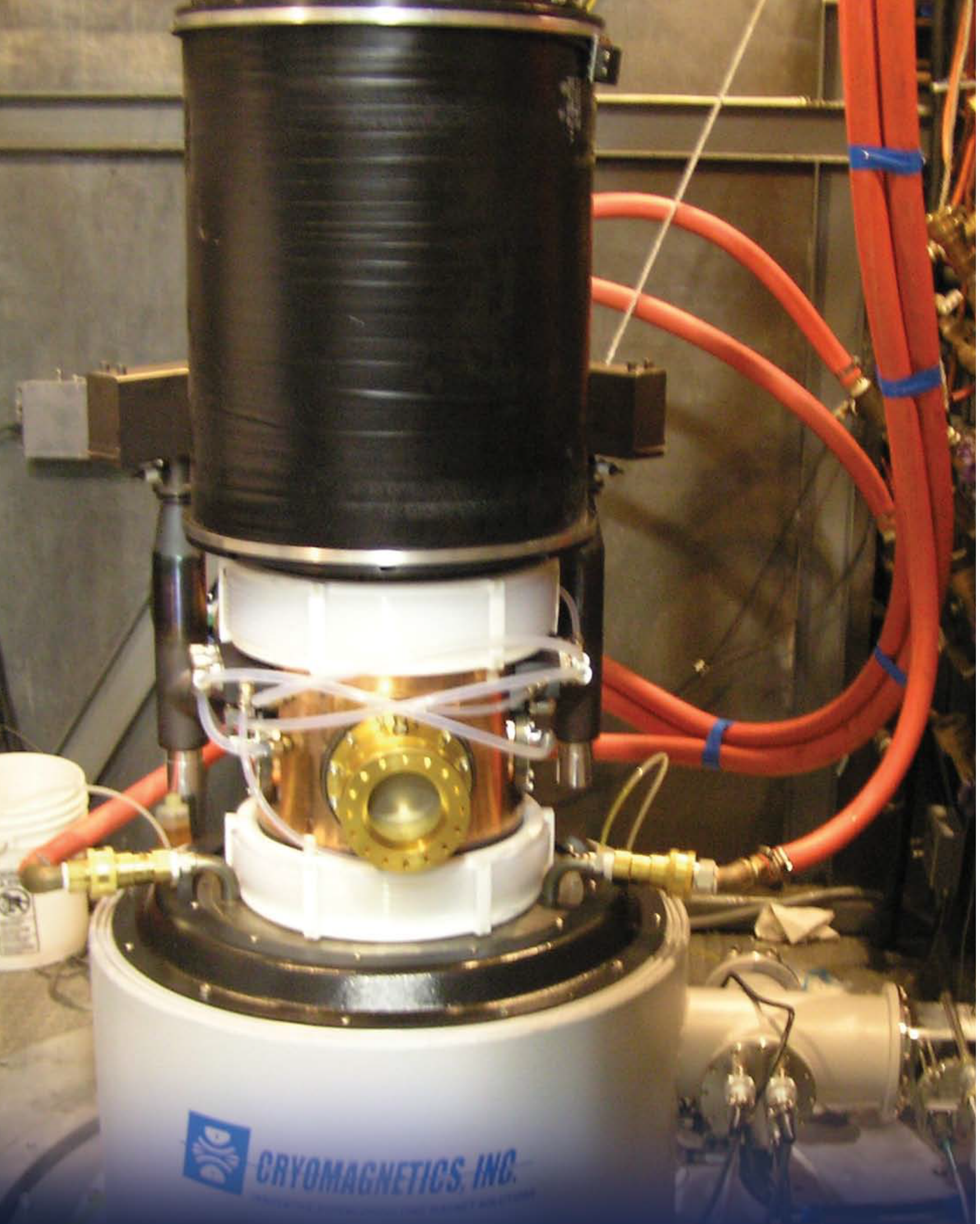
Raw Image

Previous Product



PCID Recovery

AFRL's newly released PCID–based processing capability provides images of space objects faster and at much higher resolutions than previous software products (including earlier PCID versions) were able to supply.



Shown enclosed by its superconducting magnet, this 2.5 MW gyrotron, developed jointly by AFRL and industry, has already produced 1.7 MW of power and is undergoing further improvements to increase this world-record output

No Denying World-Class Gyrotron Power

AFRL is working with the Microwave Power Products Division of Communications & Power Industries, Inc., to develop a 2.5 MW gyrotron as the millimeter wave source needed for fielding airborne active denial systems (ADS) aboard Special Operations Forces (SOF) aircraft. While airborne active denial poses numerous challenges, gyrotron development represents the most critical of these hurdles, since this one component forms the basis of the entire system concept. Accordingly, this enabling technology must be capable of operating not only at threshold power levels, but with reliability and consistency in the formidable flight environment. During the team's most recent test series, the in-progress gyrotron achieved world-record output power of 1.7 MW. Once completed, the device will be 25 times more powerful than current ground-based ADS capability.

Civilian wartime casualties dramatically affect public opinion, both at home and abroad. Many such casualties stem from the warfighter's lack of nonlethal options for discouraging aggressive behavior, whether displayed by individuals or among crowds. A key element of nonlethal weaponry is active denial, a technology that can significantly assist coalition troops in gauging hostile intent and deterring actions that might otherwise elicit the use of lethal force.

Initiated in the early 1990s, AFRL's Active Denial Technology program sought to demonstrate the effectiveness and safety of using 95 GHz radio frequency radiation to provide personnel a strong but nonlethal deterrent. Since its inception nearly two decades ago, the program has completed a successful Advanced Concept Technology Demonstration (ACTD) involving the enactment of five ACTD Memorandums of Understanding and Memorandums of Agreement, as well as the construction—and subsequent demonstration—of three ground-based systems.

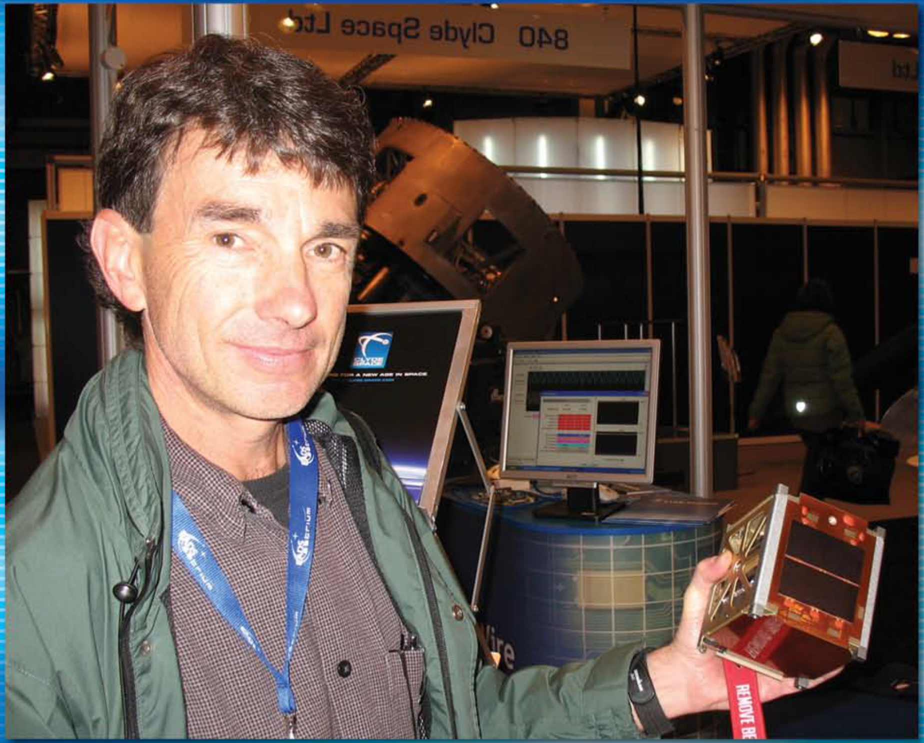
Recognizing that the integration of active denial technology into an airborne SOF platform would permit longer-range engagement of potential threats and, thus, enhanced capacity to identify intent and (if necessary) justify escalation of force, AFRL proceeded to establish the Airborne Active Denial Technology (AADT) program. As the program name implies, AADT efforts have focused primarily on reshaping ground-based active denial as an airborne—and particularly SOF-based—utility. The successful outcome of AFRL's recent gyrotron testing marks an important step towards realizing this urgently needed warfighter capability.

ASTRIA Resource a Valuable National Asset

Since its inception, AFRL's Advanced Sciences and Technology Research Institute for Astrodynamics (ASTRIA) has provided an avenue for innovative solutions to current and future problems with astrodynamic context. Accordingly, the research entity has been able to solve a variety of defense-related space control issues, several of which have involved key improvements in resident space object (RSO) data tracking and association and in RSO orbit determination via automated, near-real-time, statistically based algorithm design, development, and implementation. To address operational hazards stemming from the growing population of RSOs—which do occasionally collide, get lost, and experience failures—ASTRIA is now working with the National Aeronautics and Space Administration's Goddard Space Flight Center to codevelop next-generation astrodynamics software providing more timely, realistic, and autonomous RSO identification and discrimination.

ASTRIA combines in-house government and contractor expertise with an academic consortium focused on (6.1, 6.2, and 6.3) research in astrodynamics-based science and technology of interest to AFRL and the Department of Defense. ASTRIA, which currently consists of universities allied with AFRL's extensive and dedicated exploration of directed energy and space vehicles capabilities, has a Board of Advisors (BOA) comprising government staff of the authority to supply recommendations and oversight guiding ASTRIA research endeavors. This advisory structure ensures not only that ASTRIA's activities are aligned to a successful path of technology transition, but that they remain relevant to ever-changing warfighter needs. Accordingly, the ASTRIA BOA meets annually in order to pinpoint "challenge areas" for research and development. Subsequent to the BOA's yearly forum is an annual workshop, where ASTRIA research teams gain exposure to the board's recently identified focal points and begin working to devise—or update existing—plans for tackling these challenges.

The assembly of specific research teams from ASTRIA's overall membership occurs through various means. Government/university alliances known as Education Partnership Agreements represent one such (extensively used) mechanism. Other common channels for participation include the postdoctoral arrangements, sabbatical leaves, and similarly personal measures employed by individual professors and students. ASTRIA project engagement is also possible via Intergovernmental Personnel Act, AFRL Air Force Office of Scientific Research–based Researcher Assistance Program, Cooperative Research and Development Agreement, and comparable methods.



ASTRIA staff attending the International Astronautical Congress (Glasgow, Scotland) demonstrate a "cubesatellite" (10 cm on each side) that presents unique space tracking challenges due to its small size.

AFRL engineers created the pictured seat cushion—which employs "air bladder" technology for relieving pressure and promoting proper blood flow—in response to aircrew feedback regarding the physical aches and pains of lengthy flights.

Crew Comfort No Backseat Concern for AFRL

AFRL engineers didn't take requests from deployed troops lightly, but they did take the feedback sitting down—literally. Fortunately for personnel engaged in long-duration flights, this approach—founded in complex and interrelated human factors considerations—proved effective for resolving the physical discomforts of sitting for prolonged periods during these lengthy missions. To address this well-documented operational need, the lab's Biosciences and Performance Division, Vulnerability Analysis Branch developed, tested, and delivered dramatically improved seat cushion technology.

The engineers evaluated multiple cushion technologies in terms of comfort, impact safety, ejection sled compatibility/performance, environmental factors, and aircrew feedback gathered during simulator testing. The cushion best satisfying these assessments—and ultimately chosen for flight test—employs "air bladder" technology, which incorporates a small motor and battery pack to cycle air in order to alternate pressure and promote blood flow to the occupant's extremities. The selected cushion is more comfortable than the standard, ACES II [Advanced Concept Ejection Seat] variety and just as safe. Adding to these advantages is the new cushion's capacity for drop-in replacement of current ACES II products.

Coordination with the AFRL Flight Safety Office, the B-2 System Program Office, Warner Robins Air Logistics Center, and Air Combat Command facilitated AFRL's fall 2009 delivery of the new cushion to the 509th Bomb Wing for 4-month developmental flight test. The technology subsequently underwent F-16 operational flight test—19 sorties totaling ~23 flight hours—at the Air Force Flight Test Center (AFFTC), Edwards Air Force Base, California. Test results prompted AFFTC's affirmation of the cushion's suitability for further in-field evaluation in operational aircraft. Accordingly, long-duration operational flight test aboard foreign military sale ferry-flight aircraft is slated for spring 2010.

I/ITSEC Exhibits Reflect Advantages of Collaborative Training Research

While warfighter preparation is no game, AFRL human performance expertise reveals that it nonetheless *benefits* from games—game-based military training and simulation, that is. Featuring technology developed and transferred via Cooperative Research and Development Agreement–enabled collaborations with private industry, AFRL demonstrated the value of interoperable gaming environments for building warfighter knowledge and skills. The venue for this technology exhibition was the 2009 Interservice/Industry Training, Simulation, and Education Conference (I/ITSEC), held in Orlando, Florida.

An ongoing activity for AFRL is the creation of interactive gateways permitting—via interface controls and exchanges—commercial game-based environments to function seamlessly, both with each other and with the lab's Live-Virtual-Constructive (LVC) training concept. AFRL's I/ITSEC activities revealed that by collaborating to integrate existing technologies to form a comprehensive, "family-of-complementary-trainers" enterprise, engineers can decrease development time while increasing the training value of constituent technologies.

AFRL also showcased another impressive technology stemming from cooperative endeavors—namely, a voice-enabled synthetic agent system called the Virtual Interactive Pattern Environment and Radiocomms Simulator (VIPERS), which arose from a partnership with Air Education and Training Command and CHI Systems, Inc., to leverage Joint Technology Center/Systems Integration Laboratory (JTC/SIL) resources for Air Force Synthetic Environment for Reconnaissance and Surveillance (AFSERS)/Multiple Unified Simulation Environment (MUSE) resources. As the JTC/SIL's cornerstone tool set for all military unmanned aerial system (UAS) programs, AFSERS/MUSE is the primary UAS training and simulation system used for command- and staff-level joint services training. VIPERS uses cognitive agents (software components that can behave intelligently in complex systems over extended time periods) and speech interaction in concert with desktop simulation to provide pattern-in-a-box practice tools. By enabling student pilots to practice radio communications via artificially intelligent agents, voice commands, and a simulated pattern environment, VIPERS reduces the need for human trainers and expensive systems (e.g., aircraft, air traffic control towers) and thus reduces both costs and risks. Joint tactical air controllers can use VIPERS to learn and practice real-time mission skills and effective coordination (including spoken and text-based interaction) with UAS "crews" comprising voice-enabled software agents.

I/ITSEC participants discuss a new game-based training environment that merges commercial gaming capabilities with AFRL's LVC training concept.

Housed in the Altitude Decompression Sickness Research Database of the lab's Collaborative Biomechanics Data Network, AFRL's ADRAC leverages "bubble growth" and statistical models of hypobaric chamber simulations to produce risk assessment output.

Risk Model for High-Altitude Missions Added to NATOPS

An important AFRL-developed model used by flight mission planners, operators, pilots, and commanders to gauge the risks of altitude decompression sickness in a given situation is now part of the Naval Air Training and Operating Procedures Standardization (NATOPS) program. Developed by AFRL scientists Dr. Andrew Pilmanis and Dr. James Webb and hosted on the lab's Collaborative Biomechanics Data Network (CBDN) Web site, the Altitude Decompression Sickness Risk Assessment Computer (ADRAC) model underwent official incorporation into *NATOPS General Flight and Operating Instructions*, a key program publication.

Also known as *OPNAV Instruction 3710.7 (N88)*, the text now contains CBDN Web site references, as well as several pages describing the ADRAC model as an invaluable online mechanism for assessing critical mission scenarios according to physical and physiological principles. As its title indicates, the NATOPS document prescribes general flight and operating instructions and procedures applicable to the operation of all US Navy aircraft and related activities. The addition of AFRL's CBDN-based ADRAC tool to the Navy's written governance thus marks a milestone of significant interservice impact.

Developed and maintained by personnel from the AFRL 711th Human Performance Wing (711 HPW)—more precisely, from the Human Effectiveness Directorate's Biosciences and Performance Division—the CBDN comprises a group of comprehensive human performance and measurement databases collectively representing more than 30 years of AFRL research. Contained within this Web-accessible framework are extensive data collections spanning impact acceleration, altitude, vibration, anthropometry, blast, and numerous other subject areas. The CBDN's Altitude Decompression Sickness Research Database alone contains several thousand altitude exposure records, along with the associated ADRAC model.

ADRAC's user-friendly front end enables quick determination regarding the risk of decompression sickness based on factors such as altitude, prebreathing time, and duration of exposure. Because ADRAC is a regular go-to resource for a wide range of users, including Air Force Special Operations Command and the National Aeronautics and Space Administration, 711 HPW representative Mr. John Buhrman worked with Naval Commander Michael Venable to assimilate relevant content as part of NATOPS. Consequently, the CBDN Web site and its resident ADRAC model now exist as formal components of published Navy doctrine.

Is It Live or Is It...Virtual Dome Training?

In pinpointing the Army National Guard's Grayling Air Gunnery Range, AFRL researchers may well have identified the ideal test site for their Mesa, Arizona-based Warfighter Readiness Division's Joint Terminal Attack Controller (JTAC) virtual training dome. The dome's 4 m spherical screen, which gives JTAC trainees a 160°-170° horizontal field of view, facilitates real-time visual and electronic interaction in a synthetic hostile environment.

Providing both live and simulated options, the Alpena, Michigan-based Grayling Range is the venue of choice for training more than 200 JTACs and Joint Fires Observers from the Air Force, Army, Navy, Marines, and coalition nations each year. As part of determining how best to utilize the dome for training JTACs as swiftly and effectively as possible, AFRL researchers installed the structure at Grayling, where they will explore the comparative advantages of training exclusively with live controls versus training via live controls and virtual simulation combined. The Grayling test bed will enable AFRL's examination—and where applicable, improvement—of the immersive experience so that present and future JTACs leave training able to perform at their best.

Simulator fidelity and required training time (duration) are among the areas to be examined, with investigations comparing simulators of various fidelity—some higher, some lower—to live controls. The data collected through these studies will facilitate cost-benefit assessments addressing how much time trainees need to spend in a lower- and/or higher-fidelity simulator, what affects skills decay, how often JTACs need refresher sessions to maintain proficiency, and other questions of similar importance. Along the lines of characterizing simulators according to their different uses, the Grayling effort can help to identify certain aspects of Mission-Essential Competency (MEC) training, which does not always demand the highest-fidelity simulation. On the contrary, some MEC units are perfectly well-suited to a simple desktop computer trainer, while others may require a full-fidelity simulator and/or exposure to a live environment.

Also targeted for potential exploration at Grayling are the numerous new gaming technologies—specifically, off-the-shelf flight simulation games—professed to increase training realism and, thus, skills enhancement. In addition to advantages already noted, the range can supply rated pilots to assist with man-in-the-loop aircraft station testing by flying simulated planes the way they would in real life. One proposed test calls for a control group of JTACs to perform 2 weeks of live-controls training on a range (talking to a pilot in an actual aircraft, dropping a real bomb on a real target) and another group to train on both simulation-based and live controls. This prospective approach would enable researchers to determine which of the two groups had gained more knowledge and increased their skills.

A trainee (standing) calls in an airstrike to "destroy" an enemy tank during joint combat air support training on the JTAC virtual training dome, while another trainee (seated) enters information enabling the simulated aircraft to react as intended.

A manikin fitted with a JSAM and JHMCS facilitates AFRL's recent biodynamic evaluation of the protective equipment in terms of pilot neck loads.

AFRL Unmasks Biodynamic Potential of New Pilot Protective Device

AFRL performed key biodynamic assessment of the Type II (most recent) Joint Service Aircrew Mask (JSAM), an incrementally developed head/eye/respiratory sustainment system intended primarily to safeguard individual Airmen against chemical and biological (CB) warfare agents. The lightweight mask is the first and only CB protective mask in the Department of Defense (DoD) inventory that can provide anti-g and g-induced loss of consciousness protection for aircraft operators. Fully compatible with existing life-support ensembles, the JSAM technology also defends against radiological particles, flame and thermal exposure, and hypoxia (to 60,000 ft). Suitable for incorporation into more than 60 different aircraft, both fixed-wing and rotary, JSAM use will span all US military services and summarily replace six DoD aircrew masks. The JSAM assessment entailed three Safety of Flight tests: vertical impact, horizontal impact, and windblast.

The vertical impact test structurally evaluated the JSAM, as well as to verified the consistency of various assemblies in maintaining acceptably low risk of neck injury risk during emergency escape. The team used AFRL's vertical deceleration tower to simulate catapult acceleration for the Advanced Concept Ejection Seat II (ACES II) and the seat used in B-52 aircraft, using specially instrumented manikins fitted with standard HGU-55P flight helmets to measure the dynamic loads imparted to a pilot's neck during ejection events. All equipment performed well, with no major failures or violations of injury criteria.

The horizontal impact test verified that the JSAM O_2 hose and the Joint Helmet-Mounted Cueing System's (JHMCS) quick-disconnect connector (QDC) detached at their respective torso connector mounts on the AIRSAVE [Aircrew Integrated Recovery Survival Armor Vest and Equipment] vest during ejection catapult. The team used the lab's horizontal impulse accelerator (HIA) to simulate catapult acceleration for an ACES II, along with a specially designed test fixture mounted on the HIA track to measure the dynamic load needed for O_2 hose and QDC separation. Test results showed that even with larger occupants, the combined JSAM/AIRSAVE setup will have limited impact on disconnect loads. The results also reflected the disconnect load's sensitivity to pull angle; the load for an F-15 with the JHMCS in-line release connector (IRC) 7 in. from the seat was much lower than the load for an F-16 with the IRC 2 in. from the seat.

Windblast testing confirmed the JSAM's structural integrity and aerodynamic compatibility with the ACES II during ejection. The team used the Windblast Test Facility at Dayton T. Brown, Inc., to subject the JSAM to 350-600 knots equivalent airspeed. Test results proved the JSAM sufficiently robust, with the equipment sustaining little to no structural damage.

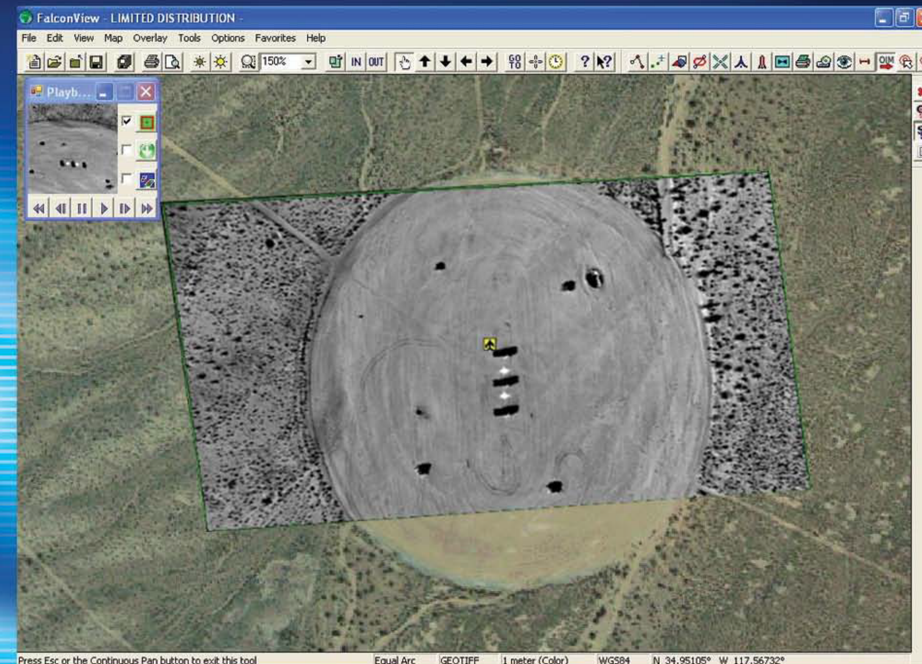
"AIMing" to Improve ISR Data Availability

With successful testing of AFRL's Advanced Information Management System (AIMS) comes a powerful new capability for high-speed recording, cataloguing, and brokering—and near-real-time dissemination—of critical intelligence, surveillance, and reconnaissance (ISR) information for tactical-edge warfighter use. The server-based AIMS employs a publish/subscribe/query architecture that leverages a combination of technologies for improving situational awareness, command and control, and targeting capabilities.

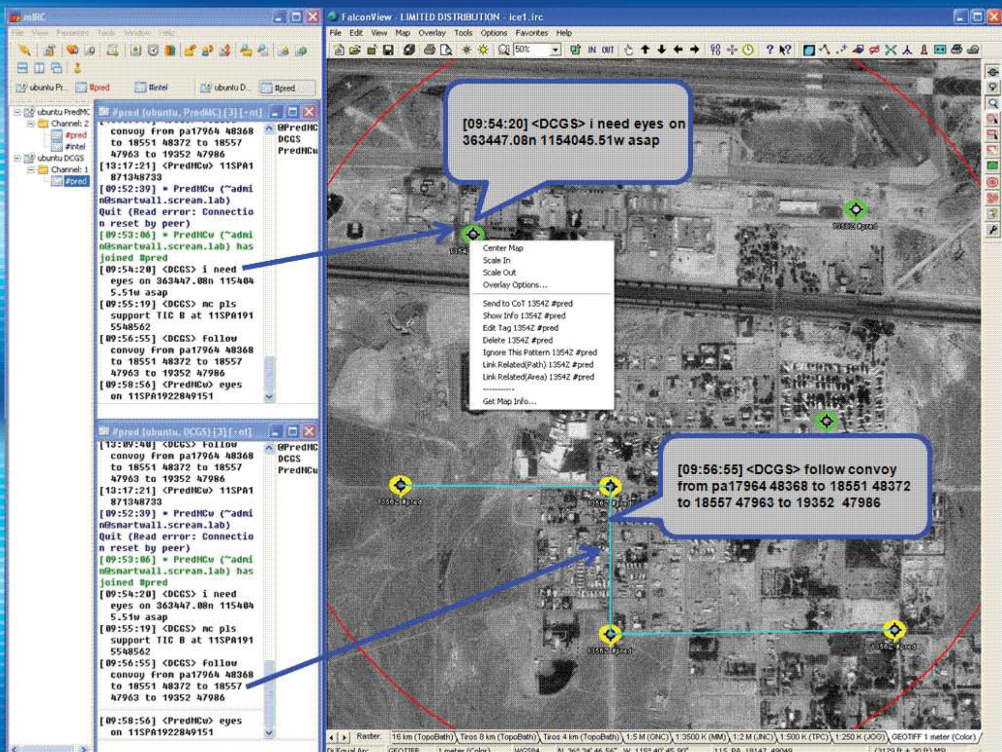
The experimental test network consisted of two primary nodes: a ground-based client node and an airborne server node flying aboard an F-16. The ground node uses an in-house-developed FalconView plug-in, incorporated both for its inherent mapping utility and for its interoperability with the Battlefield Air Operations Toolkit. The server node flies as a LITENING targeting pod component.

Using a direct interface to high-resolution forward-looking infrared (FLIR) and shortwave infrared sensors, the airborne AIMS recorded both still frames and video at a real-time rate of 20 frames per second. Concurrent to this activity, AIMS created and stored FLIR cursor-on-target (CoT) thumbnail image messages every 2 seconds. Each message specified the position of the respective thumbnail's four corners and included a hyperlink to the full-size image (hosted by the AIMS Web server on the LITENING targeting pod). This approach enabled efficient ground-user consumption of data from the LITENING pod–based FLIR sensors, while providing access to higher-resolution imagery if required.

Ground-based [client] users can subscribe to CoT FLIR thumbnails or georeferenced video. Further, they can query AIMS' XML database for historical CoT data and/or request that video archived on the LITENING pod be sent to the ground for review. Users employ FalconView to display the CoT image positions they receive. Thumbnails are also rendered in a separate window, the VCR-like controls of which enable back-and-forth movement through time to accommodate user searches for specific imagery. After locating a thumbnail of interest, the user can download a full-size image in the desired format (e.g., NITF, GeoTIF, RAW, JPEG) from the airborne AIMS server. During testing, users subsequently imported their downloaded NITF and GeoTIF images into FalconView in order to leverage its enhanced mapping and targeting capabilities.



The ground (client) node of AFRL's server-based AIMS uses FalconView (pictured top) for advanced mapping capabilities. The server node of AIMS resides on the airborne LITENING targeting pod (pictured bottom).



HAF demand prompted AFRL to create ICE, which collects geospatial coordinates entered in online chat rooms and plots the locations in FalconView for mapping purposes.

Chat Extractor "ICEs" the Competition

Responding to requests from the Headquarters Air Force (HAF) Intelligence, Surveillance, and Reconnaissance (ISR) Innovations office, AFRL recently delivered ICE—a new Internet Relay Chat Coordinate Extractor that monitors online chat rooms for geospatial coordinates entered during Predator/Reaper operations and automatically plots those locations in the FalconView map program.

In developing the ICE software, AFRL human performance specialists analyzed over 215,000 lines of chat logs (from past and current operations) in order to identify the variety of coordinate formats transmitted via chat. The scientists then developed a sophisticated chat parser to extract locations and send them to a custom-developed FalconView plug-in. One of the key features of ICE is its capacity to forward extracted locations from FalconView via the standard cursor-on-target messaging standard. Preliminary analysis of the parser shows a coordinate extraction accuracy of over 99%, with zero false alarms. Parser refinements are ongoing, and AFRL will forward these updates to HAF as applicable.

Several recent ICE demonstrations have earned substantial accolades from key HAF and Air Force Special Operations Command (AFSOC) personnel, who have praised the work not only as a rapid development success, but as an excellent example of AFRL's contribution to the ISR Innovations mission. Additional ICE demonstrations—including one addressing AFSOC-specific use of the tool (slated for Hurlburt Field, Florida)—will occur as interest indicates.

Materials and Manufacturing Know-How Bests Failed Breakers

In resolving a potentially costly problem related to KC-135 circuit breaker failure, AFRL developed a novel routine for checking and replacing these critical components. Affecting nearly 400 aircraft, the approach is likely to save the government nearly $5 million; expedite the delivery of critical wartime assets; and reduce the number of future missions aborted as a result of failure scenarios.

In response to reports of failed circuit breakers causing aborted flight operations at forward operating locations, preventing timely delivery of overhauled KC-135 aircraft, and otherwise negatively impacting operational tempo, AFRL personnel developed and implemented a strategy for rapidly obtaining circuit breaker samples in order to understand the proliferation of issues occurring in the field. Their investigation revealed that over 400 circuit breakers (specifically, MS25244-5s) per KC-135 aircraft could be defective and require replacement throughout the entire fleet—translating to literally thousands of breakers posing significant risk to operational fidelity.

AFRL engineers devised a mitigation process imparting minimal effect on modification production lines and operational aircraft and meanwhile maintaining fully-mission-capable rates. The method involved evaluating the circuit breakers and analyzing the results of aircraft load testing to assess both the current impact and the likelihood of subsequent damage. The engineers employed substantial problem-solving skills and knowledge of electrical materials, manufacturing systems, and physics of failure tenets to evaluate original equipment manufacturer (OEM) processes and their contributory role in the problems experienced in the field. Given the collective level of expertise in these areas, the team was able to satisfactorily discount failure modes provided by the OEM. Accordingly, this comprehensive approach effectively influenced key changes to OEM production and quality assurance techniques. Beyond identifying the root cause of failure and supplying the solution for mitigating this failure condition, AFRL also conducted follow-up testing of adjusted circuit breakers for compliance with the MS25244 specification used for other military aircraft and helped the KC-135 System Program Office develop and negotiate a course of action establishing ongoing vendor responsibility, both in terms of testing circuit breakers and in replacing hundreds of existing, defective breakers at no cost to the government.

AFRL materials engineers identified the root cause of circuit breaker failure in KC-135 aircraft (pictured) and provided a viable solution to check—and, as necessary, replace—the problematic components in nearly 400 aircraft.

AFRL teamed with NCSU and Armacell, LLC, to develop a cost-effective method for manufacturing better military tents. The materials integration approach results in a well-insulated, fire-resistant tent (demonstrator shown) that is lighter-weight, less expensive, and more durable than tents made from conventional fabrics.

Lab Shares a Stake in Better Military Tents

AFRL materials experts at Tyndall Air Force Base (AFB), Florida, teamed with researchers from North Carolina State University (NCSU) and Armacell, LLC, to develop a cost-effective materials integration approach for manufacturing improved military tents. The new method will result in well-insulated, fire-resistant tents that are lighter, less expensive, and more durable than tents made with conventional fabrics. The finished product—a demonstrator model intended for display, examination, and evaluation purposes—incorporates a compacted, closed-cell foam guarded by a tough outer fabric. These special inner and outer layers are bonded with a fire-retardant adhesive and laminated to provide impermeability and thereby further enhance fire resistance. In addition to providing a viable demonstration product, this effort generated an array of materials samples that will be put to use in follow-on analysis of the technology.

The joint endeavor began when members of the Tyndall AFB Fire Research Group embarked on a shelter textile replacement project. Their primary goal was to develop a fire-resistant, insulated shelter capable of providing suitable living conditions for personnel deployed in a variety of weather conditions. Of paramount importance was that the shelter material be capable of withstanding storage temperatures of 160°F while maintaining its fire-retardant properties. The team ultimately created a product meeting these qualifications and more. Armacell, a global leader in engineered foams, manufactured the durable, waterproof, compacted foam, which resembles vinyl (but with the texture of fine sandpaper) and is commonly used in yoga mats. NCSU, a recognized leader in nonwoven materials education and research, developed the supertough, lightweight, fibrous, and nonwoven outer textile sheet. AFRL's involvement in integrating these materials yielded a novel product about 20% lighter than—and half the cost of—conventional military tent-making materials.

In formulating their final product, the researchers evaluated the technology's three major components (fabric, foam, and coating) according to American Society for Testing and Materials International standards. They examined tensile strength and other critical performance characteristics for the nonwoven fabric and focused on key areas such as vertical flame resistance, flammability, limited oxygen index, density, compression deflection, low-temperature flexibility, tensile strength, elongation, and thermal conductivity for the foam. For the specialized coating that seals the adhesively bonded inner and outer layers, they tested for enhanced tensile strength, tear strength, hydrostatic resistance, weathering (ultraviolet xenon arc), and vertical flame resistance. This technology marks a significant step forward in providing warfighters an improved, safer living environment during times of deployment and is likewise transferable to the commercial world for a variety of applications.

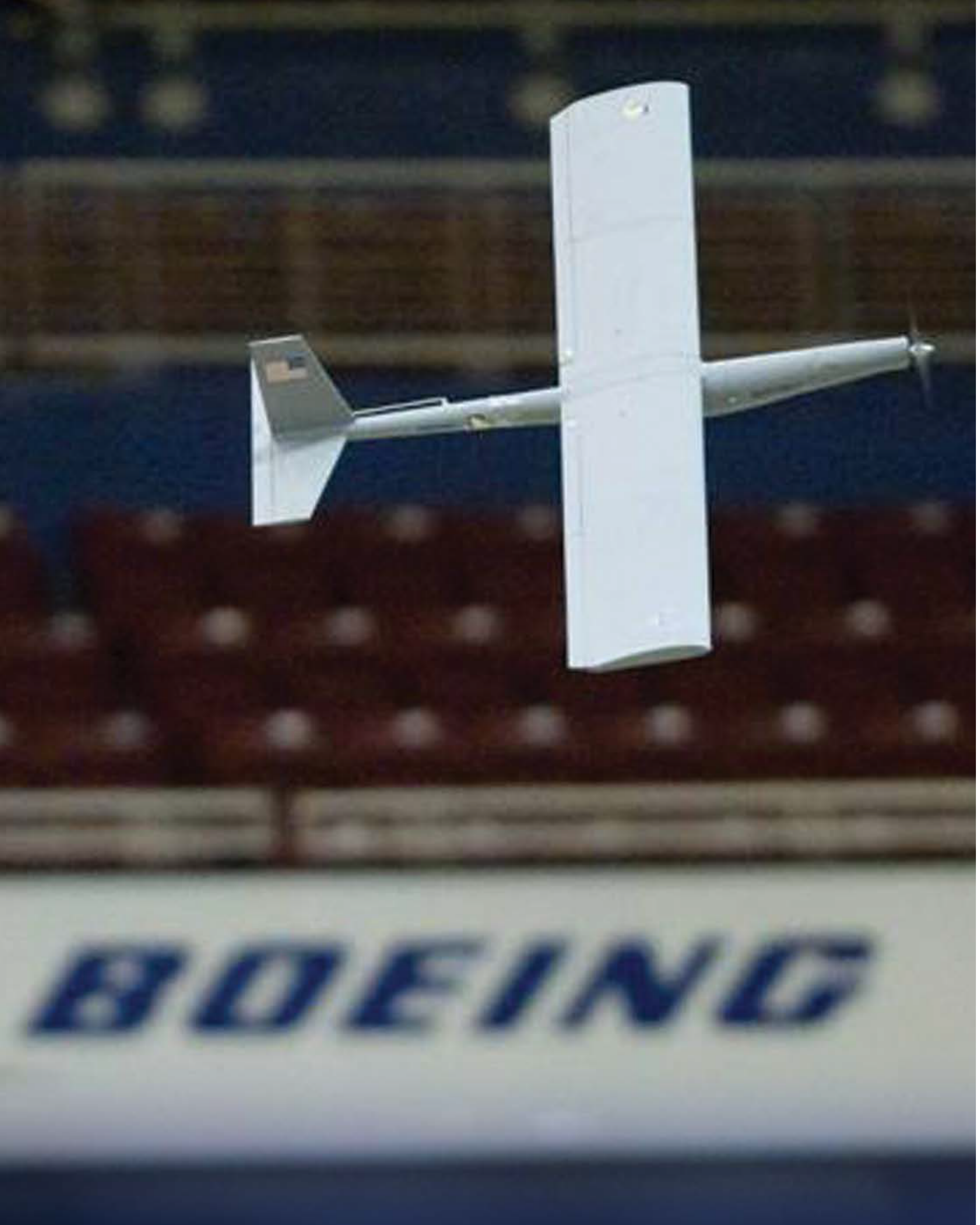
Small-Engine-Specific Research Nets Dedicated Facility

AFRL recently established its Small-Engine Research Laboratory (SERL), a state-of-the-art facility specially designed to help scientists and engineers fulfill a diverse range of research objectives related to small engines. Using SERL capabilities, researchers can better conduct experiments for optimizing small-scale propulsion and power systems performance, including work towards reducing system fuel consumption; maximizing system energy density; and improving system performance on logistically supported fuels (i.e., jet fuel, diesel, alternative fuels).

The small-scale systems (0.1-100 kW) to which the SERL caters are common to unmanned aircraft system (UAS) platforms. Further, these systems typically rely on commercial off-the-shelf (COTS) solutions that have not been optimized for military operations and thus exhibit narrow performance range; limited tuning; and specific, non-logistically-supported fuel requirements. Counter to these COTS-based limitations are the ever-expanding needs for advanced UAS mission capability, such as increased payload, range, and loiter time.

AFRL's creation of a dedicated SERL resource demonstrates its commitment to addressing these and similarly critical operational requirements, with initial SERL research already contributing—via heavy-fuel conversion technology and improved combustion controls—to a threefold decrease in fuel consumption for a Group II UAS (21-55 lbm).

Pictured are various endeavors ongoing at AFRL's newly established SERL. The SERL facility will enable key investigations pertaining to small-scale propulsion and power systems.



Boeing and AFRL flight-tested a UAV demonstrating the viable design, development, and manufacture—in less than 4 weeks' time—of a UAV capable of carrying a defined payload.

ManTech Tackles Rapid Response NFL-Style

A successful flight test conducted by Boeing and AFRL proved the feasibility of designing, developing, and manufacturing—in a dramatically streamlined process spanning less than 4 weeks—an unmanned air vehicle (UAV) capable of carrying a defined payload. The solid test performance of the UAV as an ultraportable, highly maneuverable, low-cost, and easy-to-operate aircraft—coupled with the platform's swift emergence—demonstrates the rapid response capacity to achieve desired attributes in an unmanned platform ultimately contributing to improved situational awareness for warfighters.

The test culminates an effort begun in 2009, with the AFRL Manufacturing Technology (ManTech) Division's distribution of a white paper requesting a UAV satisfying the established payload and timeline criteria. In response to ManTech's appeal, Boeing engineers set to work leveraging direct digital rapid manufacturing techniques to create thermoplastic UAV parts without using any tools. The team first transformed the documented requirements into a three-dimensional (3-D) design schematic and then fabricated the parts via fused deposition modeling, with each component undergoing thermoplastic printing by way of a 3-D printer.

Based on this novel approach to design and assembly, activities which occurred at the company's Defense Space and Security Headquarters, Boeing was able to take the project—and its breakthrough results—from paper to flight test on time and according to schedule. The resultant Rapid Manufacturing-1 (RM-1) aircraft, a 5 lb UAV operated via remote-control joystick and powered by battery, is designed to hold a small camera for collecting battlefield imagery. The system, in its entirety, ships in an aluminum container roughly the size of a small suitcase.

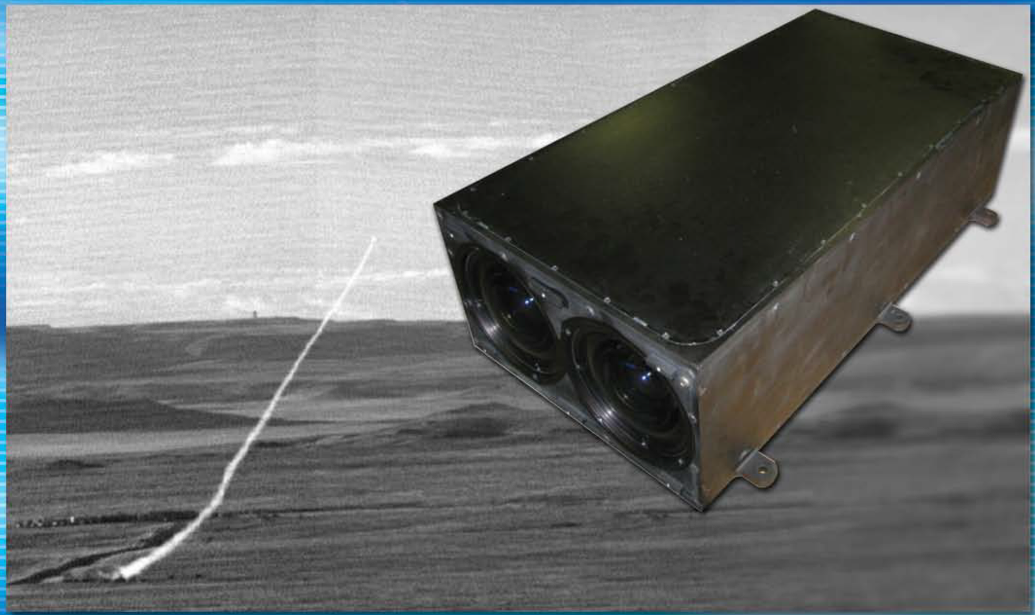
Rather than waiting months for an available government flight test group, the Boeing/AFRL team contacted officials at the Edward Jones Dome, the stadium used by the National Football League's (NFL) St. Louis Rams, regarding the possibility of performing the flight test there. Facility representatives granted permission. Because this agreement allowed testing to occur in an enclosed space, it reduced both risks and costs—specifically, the risks related to traditional open-space testing and the costs associated with observing Federal Aviation Administration regulations governing airspace limitations. During the successful test flight, which took place 24 February 2010, the RM-1 flew for 6 min and achieved an altitude of 60 ft inside the dome.

Sensors Engineers Ever Vigilant in Warfighter Response

Using Quick-Reaction Capability funds supplied by the Office of the Secretary of Defense (i.e., the Under Secretary of Defense for Acquisition, Technology, and Logistics) for a new Air Combat Command missile warning system (MWS) technology, AFRL fabricated and tested an innovative sensor for detecting the launch and flight of shoulder-fired heat-seeking missiles. Dubbed Vigilant Sentinel, the visible-band, wide-field-of-view sensor subsequently underwent promising demonstration as part of the Navy's Large Aircraft Infrared Countermeasures (LAIRCM) missile testing conducted at Tonopah Test Range, Nevada. In addition to its inherent functional advantages, the new sensor is affordable—a characteristic that makes it a likely candidate for use by all military and large commercial aircraft against terrorist missile and hostile fire threats.

During the LAIRCM event, the engineering team tested the newly developed Vigilant Sentinel's performance against a large number of assorted missile types, including guided, ballistic, simultaneous, and countermeasure launches. The sensor exceeded expectations, successfully detecting—and collecting specific data regarding—the various launches at distances well beyond the different missiles' respective kinematic ranges.

In addition to yielding positive indications of Vigilant Sentinel's desired execution, the demonstration results helped engineers understand the novel sensor concept's capacity for maturing subsystem components, identify future improvements to system design, and otherwise advance their work in the direction of an effective and ultimately transitionable MWS capability.



A surface-to-air missile launches during testing at Tonopah Test Range, Nevada (pictured left). AFRL's Vigilant Sentinel MWS (pictured right) underwent successful demonstration during these tests.

A government/industry team developed a new out-of-autoclave method for curing BMI resins. The technology will enable fabrication of larger composite structures, lower both direct and indirect expenses, and provide field and depot maintenance personnel a practical option for repairing BMI materials.

Out-of-Autoclave Method Cures Materials and Cost Concerns Alike

AFRL Manufacturing Technology (ManTech) engineers expect a recent breakthrough in bismaleimide (BMI) resin technology to generate significant improvements in the cost and fabrication of high-performance composite aerospace structures. The discovery eliminates the need for BMI composites to be cured in an autoclave; this out-of-autoclave processing capability expands the resin's use for much larger components, as well as for field- and depot-level repairs that are currently very difficult to perform. The new technology also dramatically lowers costs, both in terms of the enormous capital investment needed for acquiring new autoclaves and with respect to the price tag of components and their constituent materials.

The BMI advance stems from a collaborative effort between ManTech, the Defense-Wide Manufacturing Science and Technology program, and Stratton Composite Solutions to reduce the weight and increase the structural performance of aerospace components. The same parties are now focused on further reducing the costs related to their groundbreaking capability, which could feasibly reduce the cost of BMI-based materials and composite component manufacturing by 40% and 30%, respectively.

BMI resins presently require autoclave curing to achieve aerospace quality; however, the many large autoclaves owned by the Air Force are already in use for existing systems and therefore inaccessible to new demand. Unfortunately, purchasing new autoclaves is extremely expensive, and there are also limits to the size of units that can be safely built and operated. Accordingly, the availability of a new processing capability—one that avoids autoclave curing altogether—is a positive force in decreasing capital expenditures. In addition to lowering equipment-related expenses, the out-of-autoclave technology increases the materials supplier base and, consequently, lowers direct materials costs. The method nets indirect savings, too. Specifically, the replacement of epoxy resins with BMIs enables bigger components to be fabricated, which significantly reduces the number of subassemblies required and drives the price of aerospace structures even lower. The new processing approach addresses other shortcomings as well, not the least of which has been the lack of a viable technique for repairing BMI components on the flight line and in the many forward depots where autoclave processing is not a possibility.

The government/industry team's initial composite processing and mechanical testing demonstrates promising results for the technology. Fabrication of a part built with existing tooling is currently under way, with AFRL and Stratton Composite Solutions slated to complete this process in May 2011.

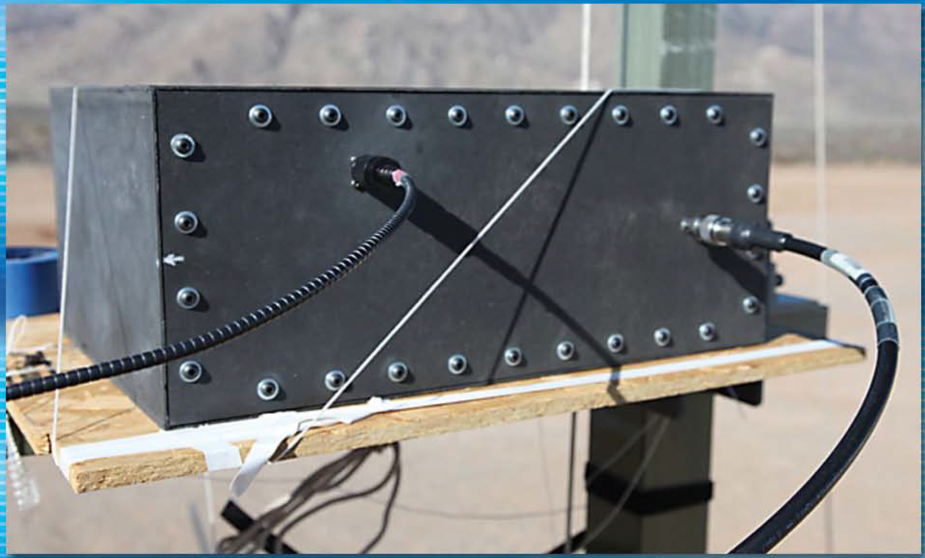
For more information contact techinfo@afrl.af.mil • (937)255-6469

HPM Tests Mark Advanced Flight Control Progress

A multidisciplinary team of AFRL researchers recently completed a series of high-power microwave (HPM) tests ultimately aimed at reducing the susceptibility of modern air vehicles to potentially damaging electromagnetic, or radio frequency (RF), sources. Conducted at the US Army's HPM facility in White Sands, New Mexico (and in conjunction with the US Army Survivability, Vulnerability, and Assessment Directorate), the testing reflects AFRL's ongoing efforts to validate the use of optics—rather than conventional electronics or hydraulics—for the aircraft flight control systems of tomorrow.

Air vehicle command and control typically relies on fiber-optic cables, the benefits of which include their capacity to transfer data at high speeds and their immunity to electromagnetic interference (EMI). In these systems, however, certain components remain susceptible to EMI and must be protected. The purpose of AFRL's recent test series was to gather data on various HPM sources with the potential to impact these vulnerable flight control components.

Accordingly, the researchers subjected several materials both to narrowband RF sources and to wideband sources, an approach that effectively mimics high-risk conditions. Among the materials tested were two—the ultradense alignment-tolerant (UDAT) fiber-optic cable and the nickel nanostrand (NiNS) composite electronics enclosure—that demonstrated preliminary suitability as possible vehicle protection candidates, with both materials tolerating the RF exposure well. Specifically, the test results indicate that the UDAT cable exhibited no significant EMI leakage, while the NiNS enclosure provided shielding equal to—or, in some cases, better than—that provided by an aluminum enclosure of the same dimensions. Based on the test data recorded, AFRL plans to investigate further design considerations with respect to this technology.



Pictured is the recently tested NiNS composite electronics enclosure with the ultradense alignment-tolerant fiber-optic cable attached.

United States Air Force Academy cadets (pictured) assisted AFRL in conducting FalconSAT-5 operational test at Edwards AFB.

FalconSAT-5 Tests a Win-Win for AFRL/Academy Interests

United States Air Force Academy cadets assisted the AFRL workforce at Edwards Air Force Base (AFB), California, in conducting recent FalconSAT-5 operational testing. Historically, the collaboration between the two organizations has proven mutually beneficial, and this recent activity is no exception. While cadets and faculty acquired a wealth of real-world, hands-on experience of relevance to operational endeavors, AFRL reaped rewards in terms of the program cost efficiency gained in leveraging the relationship. Collectively, these advantages translate to better contributions towards Air Force mission success.

The primary mission of FalconSAT-5, a satellite being integrated and flown by the Department of Defense Space Test Program and supported by AFRL, is to collect space weather measurements via a network of onboard sensors and remote ground sites. The program's multidisciplinary aspects, from operations and finance to engineering and program management, not only encompass critical needs in the area of space technology, but strive to address these needs by promoting the education and experience of space professionals.

The Edwards AFB–based test activity focused on validating the spacecraft's various subsystems (including its thruster, which is an AFRL-provided payload). Testing occurred in AFRL's newly upgraded Space Propellants Environmental Facility, a 30-foot-diameter spherical vacuum chamber. The large physical size of the chamber, as well as its capacity for high vacuum pumping speed, enabled the team to test the satellite in conditions closely emulating the space environment. Spanning just 2 years start to finish, the FalconSAT-5 program achieved a notable milestone in terms of its origination as a blank-sheet effort and culmination in a satellite implementation.

ICE-T Quenches Need for Advanced Unmanned Capability

As part of the Intelligent Control and Evaluation of Teams (ICE-T) project, AFRL researchers recently demonstrated the integrated use of coordinated unmanned air vehicles (UAV), an unmanned ground vehicle (UGV), and a ground control station and thereby made substantial headway in the advancement of UAV technology development. The specific intent of the demonstration, which took place at Vandenberg Air Force Base, California, was to showcase integrated unmanned technologies to organizations that could potentially benefit from this research. Unmanned technologies represent a potential game-changing tool for the modern warfighter. Unmanned air and ground vehicles can perform many vital tasks, not the least of which involve intelligence, surveillance, and reconnaissance (ISR) and payload delivery. The capacity to use UAVs cooperatively—sharing tasks and coordinating activities—expands their range of capabilities. Taking the technology a step further and using these coordinated UAVs in conjunction with UGVs broadens the utility of unmanned vehicles in area and perimeter security operations.

During the demonstration, two small BAT-3 [battlefield air targeting] UAVs, a slightly smaller Unicorn UAV, and a UGV system received taskings to perform three different scenarios. As the UAVs performed coordinated overhead surveillance, the Vigilant Spirit Control Station controlled the UAVs; exchanged target locations between the UAVs and the UGV; and displayed video data gathered by the UAVs, the UGV, and a security camera. The UGV moved throughout the area to interrogate and engage simulated threats. The interacting technologies completed all tasks successfully, with data successfully gathered, video displayed, and unmanned vehicles working successfully in coordination with one another. These ICE-T program technologies could foreseeably undergo transition for use in a variety of applications requiring layered ISR via unmanned assets.

Vigilant Spirit Control Station interface

AFRL-developed Pursuer technology provides users a GUI for assimilating multisensor imagery and metadata for review in one composite display.

Pursuing Multisensor GUI Advances

AFRL sensors scientists have developed a graphical user interface (GUI) capable of assimilating wide-area motion imagery, ground-based sensor data, and narrow-field-of-view sensor overlays for review in one composite display composed of multisensor imagery and associated metadata. Dubbed Pursuer, the technology builds upon the National Aeronautics and Space Administration's (NASA) World Wind Java, a software engine that overlays NASA and US Geological Survey satellite imagery, aerial photography, topographic maps, and publicly available geographical information system data on three-dimensional models of earth and other planets. Accordingly, AFRL's Pursuer provides a time model that enables users to step through a collection of sensor data in a "TiVo-like" (i.e., digital-video-recording-type) capacity. The technology also incorporates a variety of additional tools—such as frame-to-frame stabilization, brightness/contrast adjustment, user markup annotation, screen capture, distance calculator, manual tracking, and movie creation—enabling users to exploit the captured sensor data to the fullest possible extent.

AFRL is working to further develop Pursuer by hosting the product in a collaborative software environment known as Forge.mil. Similar to the open source Sourceforge.net software development site, Forge.mil offers Department of Defense developers a secure collaboration environment controlled by Common Access Card authentication and security. Interested (authorized) parties can access the Pursuer source code under the RYA – SPADE [AFRL Sensors Directorate, Automatic Target Recognition – Spatially Diverse Electronic Attack] project on Forge.mil.

Wet Paint No Barrier to Timely, Accurate Measure of Coating Thickness

A newly demonstrated technology providing the first-ever nondestructive means to measure the thickness of specialty paint coatings during their application will generate substantial savings for the Air Force. AFRL successfully demonstrated the integration of a paint spray robot with a sensor—specifically, a miniature Class I, Division 1–compliant time domain (TD) terahertz (THz) sensor—for real-time cure monitoring of coating materials as they are applied to aircraft surfaces. By ensuring the application of coatings to the correct thickness the first time, the integrated spray booth/sensing capability will eliminate costly sanding, rework, and/or reapplication tasks, increasing confidence in coating materials and helping to ensure that production schedules—in this case, for the F-35—are met.

Aircraft maintainers commonly apply specialty coatings via robot or by hand. Despite the critical relation of coating thickness to material performance, maintainers have historically relied on destructive tests, costly and inaccurate witness coupons, or otherwise limited and unreliable measurement systems—all of which require contact with a dry coating surface. To address the issue, AFRL partnered with Picometrix and Northrop Grumman to conduct initial testing and demonstration of a noncontact TD THz instrument for in-process cure monitoring of specialty material coatings developed under an earlier, Small Business Innovation Research (SBIR) Phase II effort. With the aid of computer simulations, the team determined the optimal size of the sensing package, as well as the best location for incorporating the sensor into the automated spray system.

Key to success was the capacity to mate the sensor to the spray system without altering the production spray path or qualified procedures. While successful lab demonstrations of the integrated system occurred earlier in the program, the achievement of comparable results in a production environment was critical for program completion and subsequent technology transition. Ultimately, a production demonstration confirmed that the measurement system could be successfully mounted to the robot and accurately measure wet coating thickness during a spray event. Additional data collection, validation tests, and system deployment activities are slated to occur under a SBIR Phase II extension effort ongoing through Fiscal Year 2011. Meanwhile, the TD THz instrument is undergoing development for operation in the production line/quality assurance process at a Northrop Grumman paint booth facility. Recent tests demonstrated the TD THz system installation concept, and researchers achieved sensor operation exhibiting no loss in fidelity or electrical interference with the sensor signal and thus enabling high-quality measurements over the range of sensor-tilt angles of interest.

Integrated with existing robotic spray booth technology, this compact collinear transceiver contributes to the first-ever nondestructive capability for sensing/measuring the wet thickness of specialty paint coating materials.

Pictured is the May 2009 launch of an Air Force Minotaur I rocket carrying AFRL's TacSat-3 and the National Aeronautics and Space Administration's PharmaSat microsatellite and CubeSat technology demonstration.

TacSat-3 Goes From Experiment to Asset

AFRL's Tactical Satellite-3 (TacSat-3) made the leap from experimental to operational asset with the June 2010 official transfer of control from the lab to Air Force Space Command at Peterson Air Force Base, Colorado. Since launching in May 2009, the 880 lb satellite has achieved a number of important milestones, not the least of which have involved its validation of first-generation modular bus technology (designed to provide flexibility for successive small-satellite missions) and its success as the premier small-satellite project to employ a formal payload selection process incorporating combatant command suggestions and flag officer panel appraisal. TacSat-3 has accordingly provided a novel set of high-quality, information-rich data that will have ongoing utility—specifically, in quantifying the applicability of imaging spectrometry—in meeting the various demands of future space endeavors.

TacSat-3's origins date back almost 6 years, beginning as part of the Operationally Responsive Space Initiative addressing the military's requirements for rapid, flexible, and cost-effective systems operating in the cosmos. The effort has constituted a historic mission in this respect, from the satellite's initial rapid checkout to its successful validation of the primary payload ARTEMIS, the Advanced Responsive Tactically Effective Military Imaging Spectrometer. Among the highlights of TacSat-3's nearly 13 months of experimental flight are its involvement with assisting Haitian and Chilean earthquake relief efforts; collecting approximately 2,100 images taken by the ARTEMIS sensor; performing inaugural in-space evaluation and employment of plug-and-play technology for the AFRL-led Space Avionics Experiment; using the Office of Naval Research–sponsored Satellite Communications Package to transmit, within 10 min of call-up, information obtained from ocean-based buoys to a ground station; and assisting in a US Army tactical concept of operations demonstration of a space-based intelligence, surveillance, and reconnaissance system.

TacSat-3 has demonstrated the advantages of hyperspectral information availability for warfighters worldwide. Having accomplished all key program objectives, the pathfinder technology awaits the challenges of the operational arena. The effort, including the invaluable partnership forged between government and industry, exemplifies the feasibility of achieving high-value capability on a small budget and in a short time frame.

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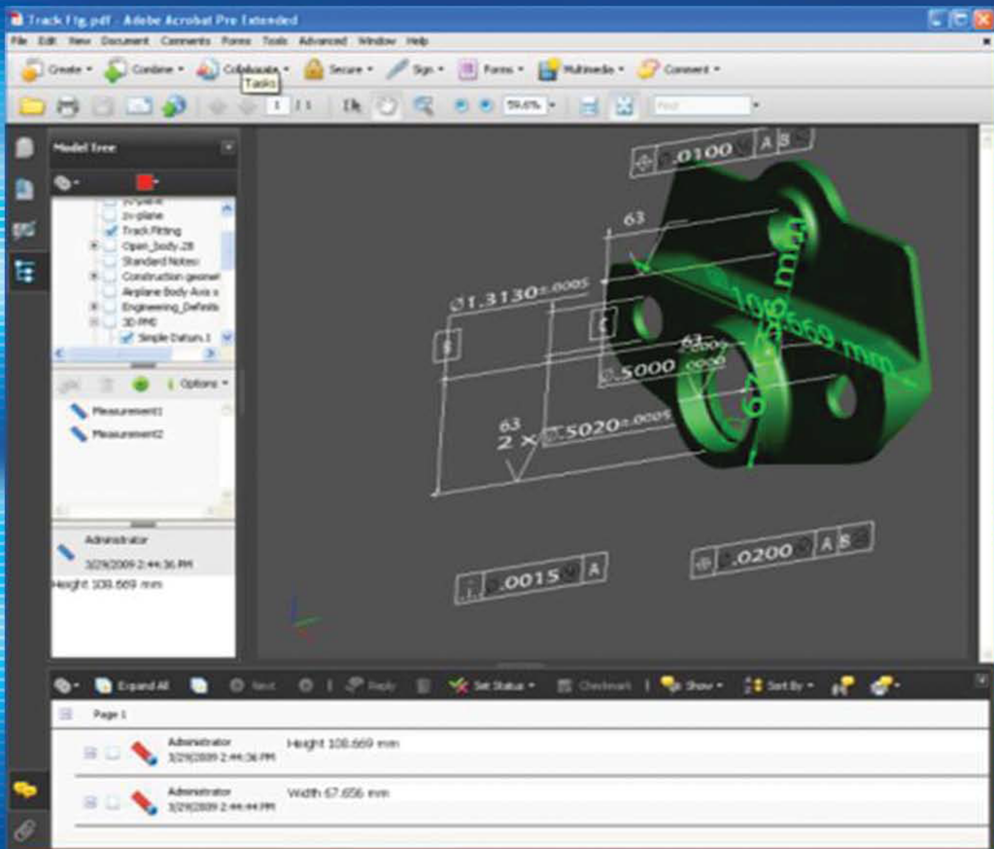
Multidisciplinary Team Dishes Up Portable SatComm Device

A cross-directorate collaboration of AFRL researchers developed a novel communications satellite antenna reflector, or dish, that is 60% lighter and more easily transported than its bulky aluminum predecessor. Composed of nickel (Ni) nanostrand composites and segmented into six pieces that fit into a backpack once disassembled, the 11.64 oz, 18 in. dish has not only a smaller logistical footprint than its one-piece forerunner, but greater durability, lower maintenance demands, and lower life-cycle costs as well.

To address the need for military field personnel to have a more transportable technology facilitating reliable communications with friendly forces, AFRL scientists and engineers joined forces to devise a satellite dish that, compared to existing units, offered similar performance but better portability. Working with industry partners Conductive Composites Company and Eclipse Composites, the team conceived of—and subsequently created—a reflector dish constructed from Ni-based nanomaterials. Conductive Composites developed the Ni nanostrands, while Eclipse Composites incorporated the constituent materials to form the composite laminate and otherwise fabricated the dish. The team's test results revealed that operational concerns—specifically, the question of whether discontinuities between segments would reduce performance—were unfounded, with the new dish configuration exhibiting virtually no loss in this critical area.

Whereas carbon fiber composites are not sufficiently conductive for use as reflector materials, Ni nanostrands—nanoscale, three-dimensionally branched and interconnected filaments of pure Ni that are extremely conductive and resistant to corrosion—are perfect candidates. Further, when Ni nanostrands and traditional carbon composites are blended, the nanostrands' electrical properties improve greatly, while the composite's mechanical properties remain the same. The result is a highly conductive composite piece that exhibits corrosion resistance and is extremely reflective. Note that because Ni nanostrands are excellent reflectors of electromagnetic energy, they are also common to applications wherein sensitive components need to be protected from stray radio frequency waves. It is for the same reasons that they work so well for electromagnetic interference shielding that they are also ideal for reflector dishes.

A multidisciplinary AFRL/industry team developed a man-packable satellite dish (pictured) that lightens the load but maintains communications reliability for field personnel.



AFRL engineers led the development of COMET software (pictured), which blends computer modeling and manufacturing data to generate accurate cost estimates for program work.

ManTech Leads DMS&T Pursuit of Better Cost Modeling Method

The Office of the Secretary of Defense's (OSD) Defense-Wide Manufacturing Science and Technology (DMS&T) program, in partnership with the AFRL Manufacturing Technology (ManTech) Division, managed the development the Cost Modeling for Enterprise Transformation (COMET) tool, which incorporates computer-aided design models and solid manufacturing data to provide timely, accurate, program-related cost estimates and thus addresses the acknowledged fallibility of current cost-projection mechanisms. Compared to prevailing methods—which involve inefficient, line-by-line modification as designs are revised and which employ models reliant on stored, potentially dated manufacturing information—COMET prepares cost estimates in a fraction of the time and, further, ensures these estimates are complete and correct (validated). Researchers expect the technology to improve US weapon systems affordability via reduced production costs and shorter development and implementation timelines. More specifically, once COMET undergoes full-capability deployment to guide design decisions, 10%-20% overall program cost reductions are feasible.

Initiated to address widespread cost modeling inaccuracy and, in turn, the great expense and substantial technology delays stemming from this problem, the ManTech-led COMET program set out to integrate cost modeling software with design and manufacturing operations in order to achieve real-time cost estimates. During COMET's Phase I effort, researchers investigated the automated extraction of critical design features and shop floor control systems to this end, with developments in key enabling technologies and standards (e.g., Adobe 3D [three-dimensional] Portable Document Format, Standard for the Exchange of Product Model Data, Open Applications Group Integration Specification) opening the door to this reality. To date, COMET has demonstrated preliminary success both in extracting geometric design information and in incorporating manufacturing process plans, achievements that collectively ensure accurate and thorough cost estimates, minimize computational errors, and otherwise expedite the costing process. During Phase II of the project, the COMET team plans to expand data extraction capabilities, automate the transfer process, and demonstrate the full range of developed capabilities.

OSD's DMS&T program facilitates the maturation of cross-cutting defense manufacturing capabilities beyond the capacity of any single service to achieve.

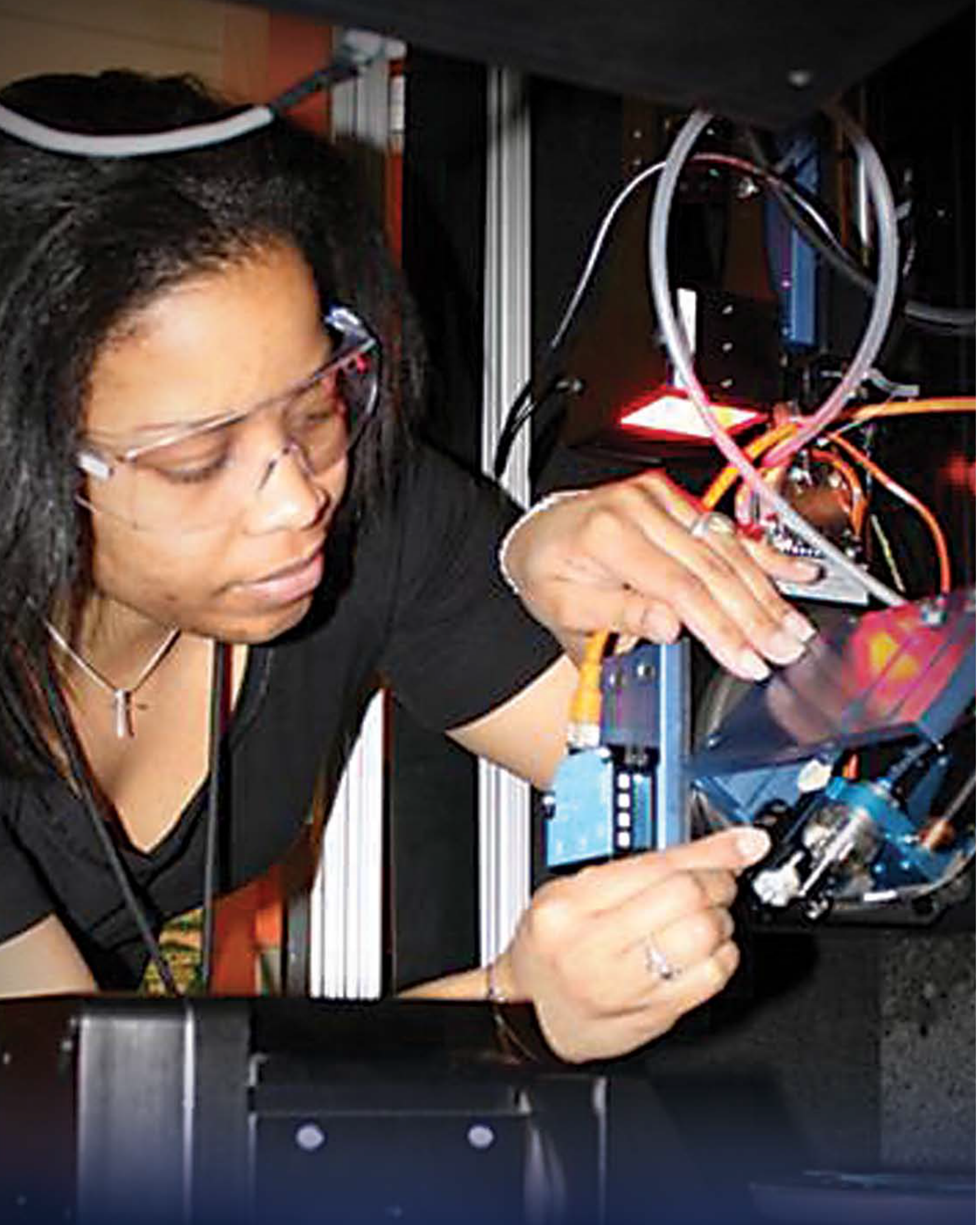
Lab Demonstrates Robotic Ground Refueling of Aircraft

AFRL demonstrated a prototype of its Automated Aircraft Ground Refueling (AAGR) system, which leverages robotics technology that significantly improves personnel safety. Though ground refueling equipment has advanced over time, the operation itself remains largely unchanged. It is still a manual process that involves physical handling of the fuel supply hose. Further compounding the risks inherent to this close-in activity is the routine practice of hot-pit refueling, wherein one or more engines continue to run throughout the operation. The introduction of robotic automation will dramatically decrease the potential hazards, since the technology requires fewer people near the aircraft.

A fully functional AAGR system will enable an operator to initiate refueling with the push of a button on an Operational Control Unit (OCU) several hundred feet away from the aircraft. The OCU will communicate with a computer configured to govern the actions of the robot, which is itself tethered to a fuel hydrant by a pantograph. This multijointed, moving pipeline follows behind the robot and supplies it with fuel. A vision-based guidance system will direct the robot's movements, with vision and proximity sensors observing the aircraft's location and the robot's path of approach. After this guidance system confirms aircraft type, orientation, and fuel door location, the robot will move to position itself near the fuel door. Accurate angular measurements guide the robot in aligning the fuel nozzle with the aircraft's single-point refueling (SPR) adapter. After the robot has attached the nozzle and completed the refueling task, a similar, reverse procedure will detach and retract the robot from the aircraft. Throughout the process, the guidance sensors will continue to monitor the scene, registering unexpected changes in the robot's proximity to the aircraft or other objects in order to prevent unwanted contact. The OCU operators will be able to supervise the simultaneous activity of multiple robots, relying on a built-in abort function to quickly halt operations should a problem arise.

Based on the successfully validated prototype robot, the team will begin adding functionality pertaining to electrical bonding, fuel status light checks, and software compatibility with Joint Architecture for Unmanned Systems technology. Pending these upgrades, the AAGR system will be ready for field-test preparation.

AFRL's AAGR system prototype robot with fuel nozzle attached to a single-point refueling adapter inside the mock-up aircraft refueling panel. The large screen displays the user interface.



AFRL uses DW manufacturing to create new structures and integrated materials. Pictured is a researcher employing M3D, one of many DW techniques enabling the 3D deposition of functional materials directly onto a material surface.

Lab Gets It "Write" With Novel Manufacturing Methods

In leveraging direct-write (DW) manufacturing methods—most recently, one known as Mesoscale Maskless Material Deposition (M3D)—AFRL materials experts are promoting advances in new metamaterial structures and multifunctional, hybrid materials. Like other DW methods, M3D provides a means for three-dimensional deposition of functional materials directly onto a material surface. Because it enables both active and passive functional devices to be fabricated directly onto structural parts and assemblies, this capability will benefit a wide range of systems—increasing the functionality; simplifying the design; and reducing the size, weight, cost, number of components, and time to market of products such as radio frequency devices, displays, packaging batteries, antennas, and sensors.

DW refers to a manufacturing process that adds components and subsystems to surfaces by printing them on a material. It encompasses a range of viable techniques, including ink jet, microspray, quill, pen, aerosol, pulsed laser evaporation, and laser direct etching methods. For instance, the micropen system can write lines from 50 µ to greater than 1 mm wide on virtually any surface. Among the many and varied materials that can be deposited via these DW methods are ceramics, metals, polymers, biological systems, nanomaterials, and hybrid materials with viscosities from 1 to 5,000 cP (centipoise). The width of the deposited material ranges from 5 to 150 µ.

M3D, the type of DW currently undergoing demonstration at AFRL, is a computer-aided-design-driven, maskless DW technique that uses aerodynamic focusing for the high-resolution deposition of chemical precursor solutions and/or colloidal suspensions. In completing this process, the M3D system focuses, deposits, and patterns an aerosol stream of the deposition material onto a planar or nonplanar substrate using three modules. The system can write on conformal structures and over large areas. The M3D equipment at AFRL is unique in that the deposition head is positioned on a six-degrees-of-freedom robotic arm, a configuration enabling deposition onto large, irregular surfaces.

To date, the Department of Defense and AFRL have demonstrated some success in using DW to develop technologies for structurally integrated antennas. Traditionally, antenna elements and arrays are mounted to aircraft exterior surfaces and require a structural enclosure to improve aerodynamics and provide protection from the elements. Different approaches to the structural integration of antennas and other sensors have undergone demonstration with varying levels of success.

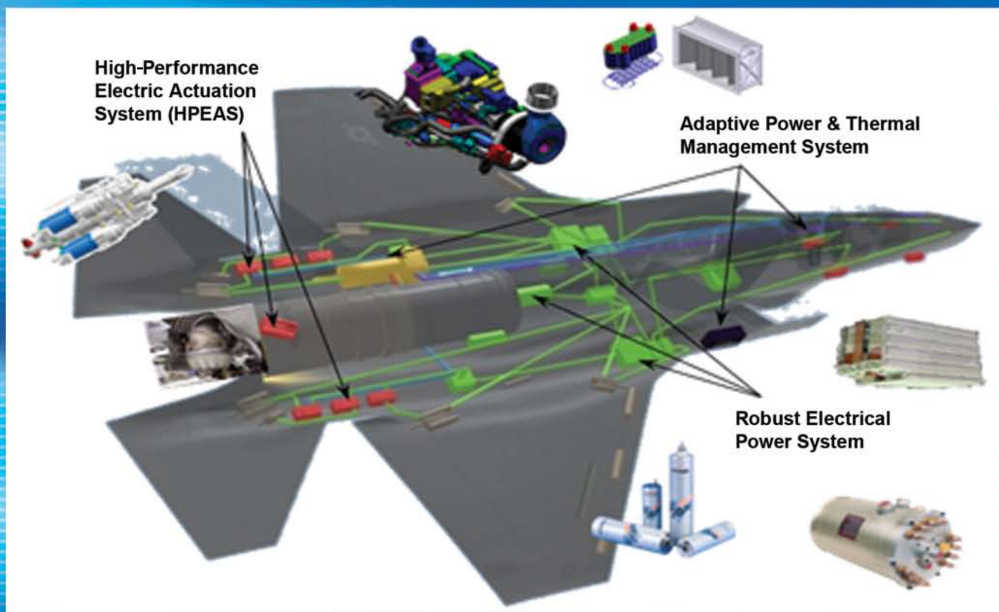
New Composite Material Skins the HTE Competition

Through its implementation of a new hot trailing edge (HTE) skin composed of the composite material AFR-PE-4, AFRL expects to virtually eliminate field repairs, reduce downtime, and achieve higher mission capability rates for B-2 aircraft. The successfully demonstrated skin confirms AFR-PE-4's viability as a more durable, higher-performing material in addressing sustainment challenges related to the B-2's current HTE. The outcome also showcases the coordinated efforts of personnel from AFRL; Hill Air Force Base, Utah; and the University of Dayton Research Institute and further boosts B-2 Program Office confidence regarding plans for an on-aircraft demonstration.

Located behind the exhaust nozzles on the aircraft's upper surface, the B-2 HTE experiences repeated thermal and vibro-acoustic stress. The polyimide material presently used for HTEs degrades quickly in this operational environment; as the incessant exposure to heat and engine exhaust exceeds its capabilities, the material cracks and the resin disintegrates. Recognizing the need for a more resilient material, AFRL commenced its design of a new application based on AFR PE 4, the maturation of which culminates work started in the late 1990s. The successfully demonstrated AFR-PE-4–based design prompted the technology's transition from lab to production.

To determine the composite's suitability as an alternative to conventional material, the researchers initiated performance testing, subjecting AFR-PE-4 purchased from three separate vendors to several types of durability tests, including both long-term (1,000 hr) exposures and high-temperature exposures (in a burner rig at the National Aeronautics and Space Administration's Glenn Research Center and in a combustion chamber at AFRL). They also conducted mechanical characterization, with the associated tension and compression tests enabling determinations regarding the material's shelf life; leveraged Advanced Manufacturing Propulsion Initiative activities to develop cure cycles and identify cost drivers for the material; demonstrated material repairability (with the help of B-2 maintainers and Northrop Grumman personnel); and fabricated demonstration (2' x 2') panels in a laboratory environment before investigating a production facility build. Future AFRL activities include preparation of the demonstrated materials for flight evaluation by the B-2 Program Office. These activities will entail the evaluation of tooling, as well as the comprehensive mechanical testing of AFR-PE-4 material batches.

AFRL's newly developed skin for the hot trailing edge of the B-2 aircraft (pictured) consists of the composite material AFR-PE-4.



Tip-to-tail thermal M&S demonstrates how integrated systems affect each other's individual performance.

Tip-to-Tail M&S "ReINVENTs" the Future of Aircraft Energy Optimization

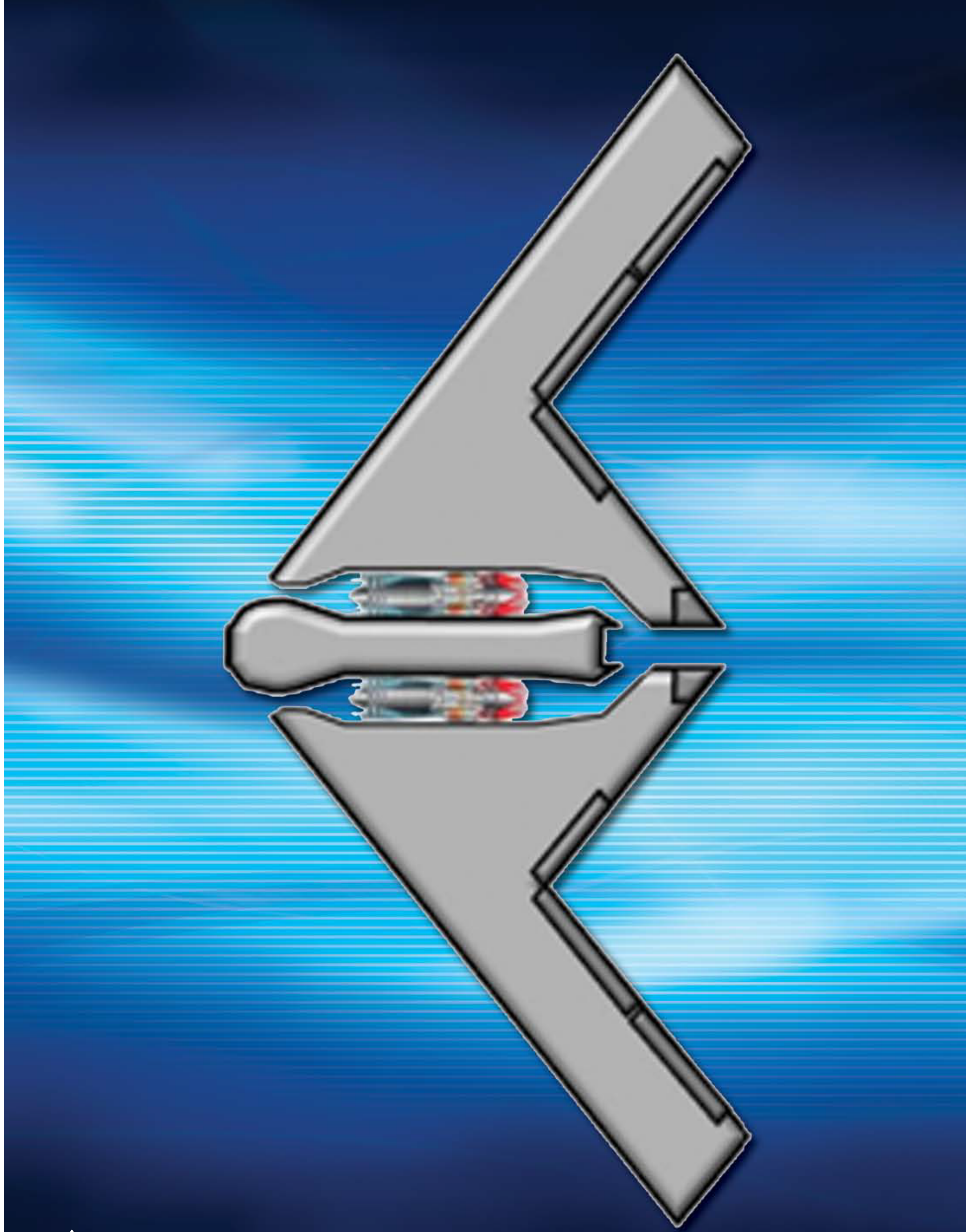
As part of AFRL's Integrated Vehicle and Energy Technology (INVENT) initiative, propulsion scientists demonstrated the first-ever practical application of aircraft tip-to-tail integrated thermal modeling and simulation (M&S). The tip-to-tail M&S approach enables researchers to understand how the integration of various air vehicle systems, fuel thermal management systems, engine systems, and adaptive power/thermal management systems can affect the respective performance of each individual system.

A primary objective of AFRL's Modeling Simulation and Test facility, where the recent demonstration occurred, is to provide researchers a capability for analyzing future energy-optimized aircraft architectures in an integrated operating environment. By simulating the concurrent operation of multiple systems throughout a full mission-profile range, researchers can establish a performance baseline for a given aircraft system's effectiveness. Simulations can then apply variations to system performance in order to investigate the effects of design trade-offs and the potential for performance improvements.

Distributed Effort, Integrated Results

AFRL's recent success in demonstrating the integration of two independent (i.e., geographically dispersed) research enclaves via distributed simulation marks a distinct milestone in the pursuit of enhanced modeling and simulation (M&S) capability as a means for reducing analysis time and cutting costs in the development phase of new Air Force systems. Resources available at the lab's Modeling, Simulation, and Test (MSAT) Laboratory facilitated the collaborative M&S experiment, which involved scientists from propulsion and air vehicles disciplines. The codevelopment environment created as a result of these MSAT technologies confirmed the viability of researchers from different research domains and physically separated locales to conduct cohesive M&S work using dynamic system models.

The primary objective was that each represented research discipline would maintain control over its own model, while the respective model would communicate with other relevant models in order to capture the salient features of the assimilated systems. The team demonstrated the distributed M&S proof of concept by connecting an aircraft system model to a propulsion system model and thus uniting two diverse Wright-Patterson Air Force Base (WPAFB), Ohio, facilities. The computer simulation model joining the two research entities enabled their direct collaboration, including the capacity for users to share technology approaches and system design tools. While this positive demonstration outcome reflects two WPAFB in-house locations, the enabling technology behind this relatively small-scale success has substantial future applicability across even greater distances and/or degrees of remoteness.



Pictured is a simulation model used for the recent demonstration effort.

(Pictured top) AOS team's chemical rubber removal system. (Pictured bottom) Port-au-Prince–based Toussaint Louverture International Airport runway before and after rubber removal

AOS Team Aids Haitian Earthquake Recovery

In their development and subsequent application of a new chemical system for rubber removal, AFRL materials specialists were able to remove dangerous buildup from a runway at Port-au-Prince's Toussaint Louverture International Airport. Compact, lightweight, and requiring no in-theater support other than fuel and water, the new system provides an environmentally safe and effective chemical means for cleaning rubber deposits left on runway surfaces by landing aircraft.

According to an Australian Transport Safety Bureau report, 141 runway accidents happened worldwide between 1998 and 2007. Included in these events were situations wherein aircraft ran off the end (i.e., the departing side) of a runway, resulting in fatalities. Eighty-five percent of the incidents took place during landings, with runway rubber buildup cited as a contributing factor to the ensuing accidents. When an aircraft lands, its tires are not spinning. Friction between the tires and pavement surface causes a chemical reaction that transforms some of the rubber into a sticky substance that adheres to the pavement, hardens, and becomes slick when wet. Each time an aircraft lands, over 1 lb of this substance (per tire) spreads over the runway, accumulating in layers. Consequently, repeated landings can cause a runway surface to become extremely slippery, rendering the process of landing and stopping both difficult and unsafe.

Following Haiti's 7.0 magnitude earthquake in January 2010, airport traffic increased from 13 to 200 flights per day. The discovery of medium-to-heavy rubber buildup on the runway prompted the Air Force Civil Engineer Support Agency (AFCESA) and US Southern Command to leverage the unique expertise and capabilities of the Tyndall Air Force Base (Florida)–based Airbase Technologies Division's Aircraft Operating Surfaces (AOS) team. Accordingly, the AOS engineers created a system comprising two primary pieces of equipment: a Bobcat® Toolcat™ (equipped with a broom and skid-loaded spray attachment) as the main vehicle and a PBM Supply & Manufacturing, Inc., nurse trailer (equipped with dust-control spray nozzles to provide water in the absence of a water vehicle at the site). The AFCESA-funded system's secondary equipment included pumps for dispersing detergent and the water, as well as detergent and water applicators for keeping the runway damp during agitation.

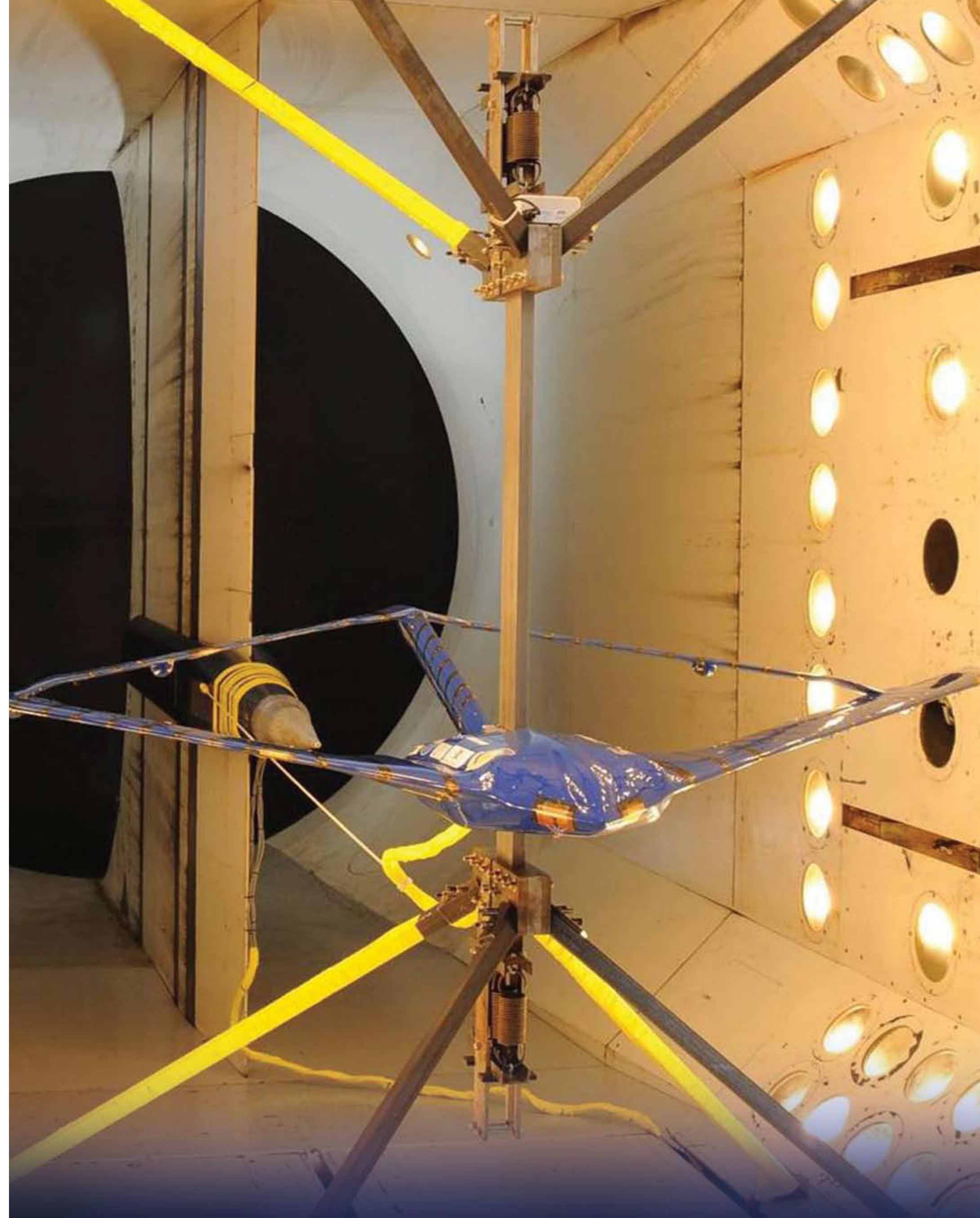
In approximately three, 8-hour shifts, four AOS team members cleared 125,000 ft^2 of rubber buildup from the runway's west end and 75,000 ft2 from the east end without damaging the pavement surface. This project contributed to Haiti's recovery as a part of Operation UNIFIED RESPONSE. It also demonstrated the unique capabilities of AFRL's AOS team and, further, served as an opportunity for evaluating the system under real-life conditions.

Singular Setup Joins Wings—and Future UAVs—to Aerodynamic Efficiency

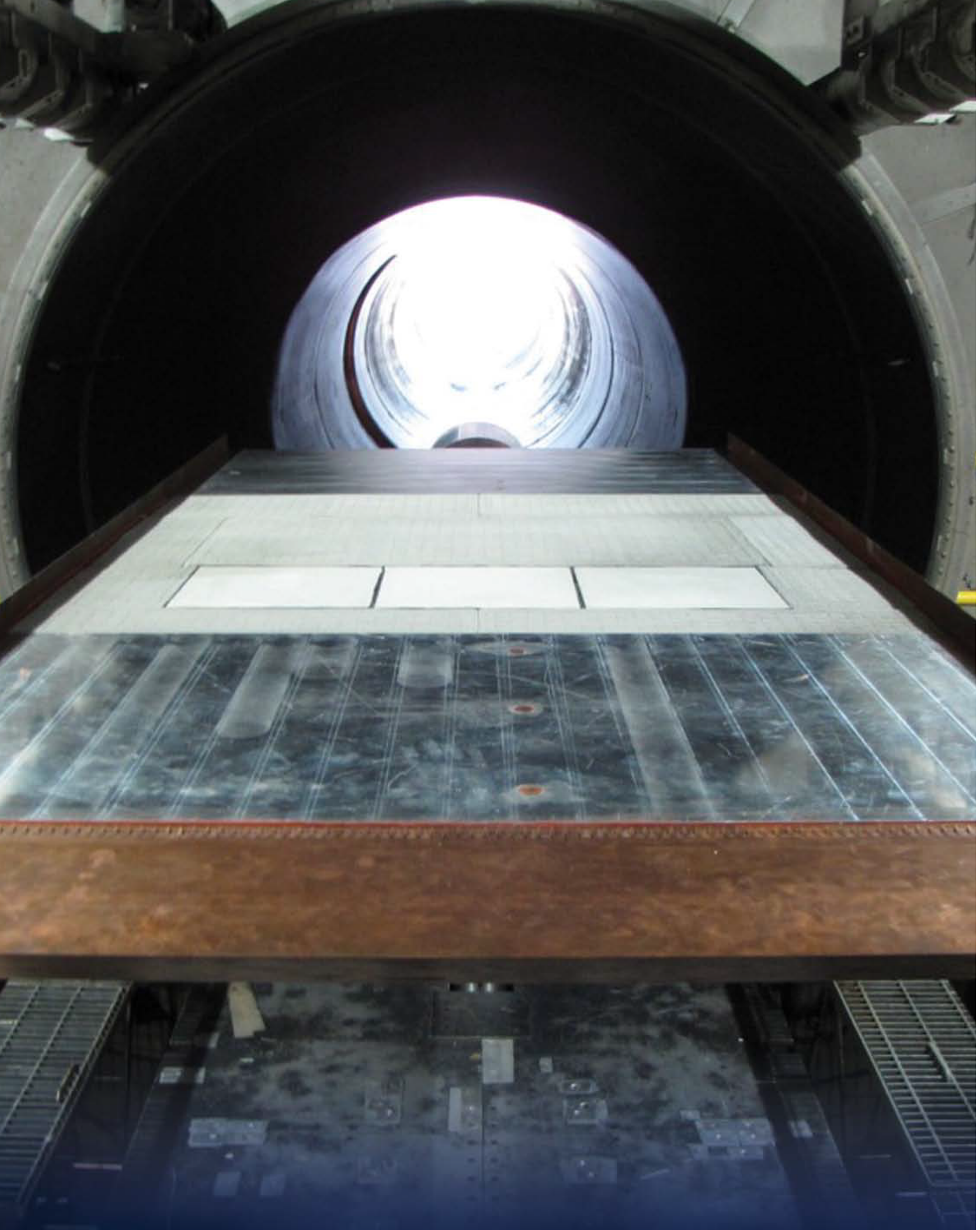
In completing key wind tunnel tests of a new unmanned air vehicle (UAV) design known as the Joined-Wing SensorCraft, AFRL engineers are a step closer to establishing the novel configuration as a cutting-edge foundation for the next generation of unmanned capabilities. Conducted as part of the Aerodynamic Efficiency Improvement (AEI) program, these tests—which involved a scale model of the craft—are among the many ongoing efforts to develop technologies enabling the longer-range, more-fuel-efficient, and lighter-weight UAVs necessary for supporting the high-altitude intelligence, surveillance, and reconnaissance (ISR) operations of tomorrow.

The new SensorCraft design features a unique, diamond-shaped wing structure that maximizes both lift and sensor coverage. The setup also incorporates Gust Load Alleviation (GLA), a dynamic controls technology that actively adjusts wing surfaces to reduce turbulence-induced stress. The capacity for such self-adjusting behavior means that aircraft wings, traditionally designed with high rigidity in order to withstand the normal stresses caused by wind gust, can be less inherently stiff. Further, the use of GLA facilitates lighter wing structures and, in turn, reduced fuel consumption and increased range.

The recent test series, performed in the National Aeronautics and Space Administration (NASA) Langley Research Center's Transonic Dynamic Tunnel (TDT), involved three rounds of testing. In round one, the researchers established the model's baseline functionality and modulated the system to ensure full control in the subsequent tests. Round two focused on the aerodynamic fitness of the design, with the team subjecting the model to smooth airflow (and observing it to be very effective at maintaining stable flight). For the final test, the model underwent exposure to turbulent airflow in order to validate the GLA wing control system. The results indicate that the GLA technology cut gust load in the wings by 50%, enabling a 25% weight reduction that will translate to a 3,500 lb weight savings in the full-size SensorCraft vehicle to be constructed.



AFRL's Joined-Wing SensorCraft model (pictured in the TDT) is just one outcome of myriad AEI-based efforts to design next-generation UAVs capable of satisfying future ISR needs.



Front view of the 51" x 48" test sled inside the Langley wind tunnel, where both an insulating blanket and CMC-wrapped tiles underwent recent testing.

Thermal Protection Advances Subjected to Realistic Testing

In pursuit of reusable launch vehicles (RLV) capable of withstanding the extreme conditions of reentry, AFRL and Boeing engineers conducted tests of two Thermal Protection System (TPS) innovations—namely, an insulating blanket and a ceramic matrix composite (CMC)-wrapped tile—using a special wind tunnel facility at the National Aeronautics and Space Administration's (NASA) Langley Research Center. "TPS" refers to the tough, insulating external layer with which a space access vehicle must be equipped in order to reenter the atmosphere. While TPS components such as those on the space shuttle are bonded to the vehicle with adhesives, the AFRL blanket and tile are mechanically attached, making them far easier to remove and replace. Specifically, whereas replacing one tile bonded to the space shuttle requires around 150 hrs (or one bonded blanket, 50 hrs), mechanically attached TPS components are easily replaced in just 1-2 hrs. The ultimate goal is to reduce RLV turnaround time from 4 months to 4 hrs, a feat thereby expanding the capabilities and missions of these vehicles.

When space access vehicles reenter the atmosphere, they experience airflow at supersonic and hypersonic speeds, causing temperatures potentially in excess of 3000°F. NASA's unique, 8' high-temperature tunnel afforded the researchers the opportunity to test their 51" x 48" test article array in speeds exceeding Mach 6, a scenario effectively mirroring realistic reentry conditions. Both the blanket and the tile withstood the high-flow environment very well. A minor blanket deformation, thought to be the result of wind tunnel conditions that do not correspond to real-world reentry conditions, is currently under analysis by Boeing. Following full review and analysis of all test data, these articles will proceed to testing performed in AFRL's Combined-Environment Acoustic Chamber.

Collaboration Leads to New Reading Assignment

An important cultural awareness document jointly authored by AFRL's Mr. Gilbert G. Kuperman, 711th Human Performance Wing mathematician, and Wright State University's Dr. Helen Altman Klein, Human Factors/Industrial and Organizational Psychology Department professor, is emerging as a future military educational tool. Recently selected for just that purpose, the pair's "Through an Arab Cultural Lens" made its first appearance in *Military Review*, a refereed US Army journal that provides a forum for original thought and debate on the art and science of land warfare and other issues of current interest to the Army and Department of Defense.

The *Military Review* professional publication also supports the education, training, doctrine development, and integration missions of the Combined Arms Center (CAC), Fort Leavenworth, Kansas. As a major subordinate headquarters of the US Army Training and Doctrine Command, the CAC upholds a mission divided between preparing the Army for the Global War on Terrorism and transforming the force to meet future threats.

The article's esteemed selection as an educational asset earmarks it as recommended reading for personnel newly assigned to the US military training mission to the Kingdom of Saudi Arabia, a joint mission under the command of Headquarters, US Central Command, McDill Air Force Base (AFB), Florida. Meanwhile, the document is now required reading for Air War College 17th Edition, Joint Strategic Leadership, Lesson 11: Cross-Cultural Leadership and, additionally, appears in the March 2010 "Cultural Awareness and the Military" bibliography compiled by the Muir S. Fairchild Research Information Center, Air University, Maxwell AFB, Alabama.

The applied methodologies of an AFRL/academic collaboration prompted the jointly authored "Through an Arab Cultural Lens" article's selection as a tool for educating military personnel.

Pictured are the KC-135 Tanker and Calspan Learjet used during AAR flight testing.

Navigating the Realm of Automated Aerial Refueling

Moving another step in the direction of expanded Remotely Piloted Aircraft (RPA) capabilities, AFRL completed the Precision RelNav Open-Loop Flight Test (PROFT) for the Automated Aerial Refueling (AAR) program, the purpose of which is to develop technology for boom and receptacle refueling of RPA systems, as demonstrated via the existing Air Force (AF) tanker fleet. Accordingly, AAR will benefit RPA operations by extending combat radius and mission time, reducing response time for time-critical targets, minimizing the need for forward staging areas, and increasing in-theater presence. The AAR team includes a diverse set of participants from organizations across the AF, AFRL, and industry.

Conducted at Forbes Field, Kansas, the recent test incorporated updated precision-relative navigational software and gathered data intended to aid the development of a precision navigation tool for AAR-formation flight. Testing involved ten separate flights, during which a Calspan Learjet acting as a surrogate RPA flew into refueling position with a KC-135R tanker (operated by the 190th Aerial Refueling Wing of the Kansas Air National Guard). Global Positioning System–based navigational software developed by Northrop Grumman Corporation guided the aircraft into position.

All told, the successful PROFT encompassed more than 40 total flight hours and established data for 83 separate test points. These comprehensive results will facilitate the navigational system's further refinement in preparation for the second round of testing, scheduled for Fiscal Year 2011.

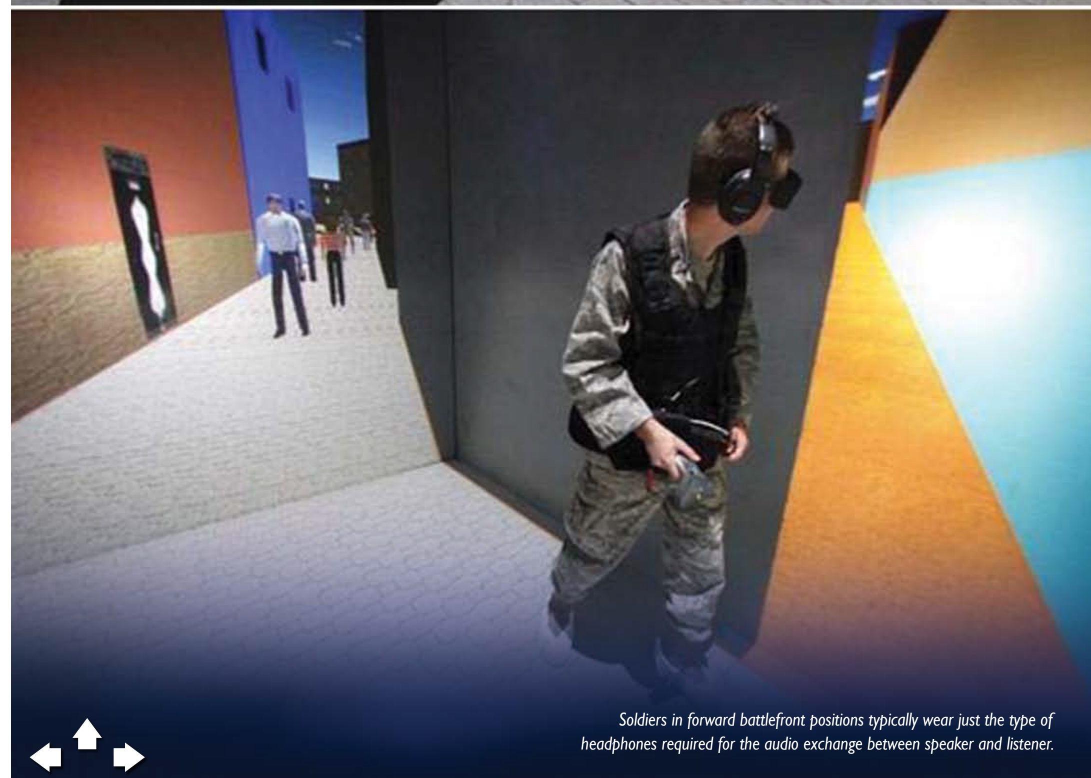
A New [Sense of] Direction for Battlefield Awareness

An AFRL/academic team is experimenting with the use of audio cues for more quickly alerting battlefield troops as to the location of sniper fire. Theoretically, the capability assumes/relies on the existence of a speaker—an individual who knows more, has more information, than the soldier engaged in the fight. He or she could be watching the area through a network of electronic monitoring sensors or from a helicopter flying above the action, for instance. The technology enables this speaker to seemingly change the direction (or apparent point of origination) from which his or her voice comes to another person, via headphones worn by that listening individual. The researchers are testing whether the speaker—who in real-world combat situations would be a military colleague, one likely viewing the action from a distance and/or through electronic means—can use that audible change in voice direction as a kind of tool for helping the listener pinpoint a sniper's position.

AFRL is funding the ongoing experimentation, which is taking place in a lab owned by Wright State University and operated at Wright-Patterson Air Force Base, Ohio. Visual "virtual reality" images, enhanced by battery-powered eyewear that creates a three-dimensional effect, flash both on wall screens and on the lab floor to give the subject a sense of patrolling through a city, wherein a sniper could be hiding in a building or around a corner. The state-supported daytaOhio center, located on Wright State's campus, has similar video capabilities and is linked with the on-base lab so that avatars displayed in both locations can operate in the same imaginary visual world and interact with each other.

To obtain plausible suggestions for improving the technology, the researchers periodically consult with Air Force and Army personnel who have been on the ground in combat situations. Once refined to the extent possible, the technology will eventually deploy to ground-based military personnel for field testing.


The Virtual Environment Research, Interactive Technology, and Simulation Chamber enables investigations of advanced audio technology that could aid warfighter combat awareness.


Soldiers in forward battlefront positions typically wear just the type of headphones required for the audio exchange between speaker and listener.

AFRL's newly patented ACCES® technology

Newly Patented "ACCESs" to Better Hearing Protection

The US Patent and Trademark Office recently assigned the Air Force Materiel Command–submitted patent application entitled "Vented Earpiece System" patent number 7,784,583. The new patent covers the lab's Attenuating Custom Communications Earpiece System (ACCES®) technology, the need for which surfaced as part of efforts to identify—and address—cockpit communications deficiencies stemming from excessive noise.

Notwithstanding the many and varied attempts to resolve pilot hearing protection and noise reduction shortfalls via existing technologies, it was not until AFRL partnered with Westone Laboratories (through Cooperative Research and Development Agreement) that ACCES® emerged as the design of choice. Satisfying all established requirements, which revolved primarily around F-22 aircrew needs, the technology promptly proved its viability with unequivocal success under all flight conditions and for all communications extremes. Consequently, the lightweight, cost-effective innovation's distinct advantages extend well beyond military pilot and maintenance (flight line) use to include industrial construction crews, heavy-equipment operators, and commercial air and ground personnel as well.

Weighing several ounces less than the conventional helmet-mounted speakers it replaces, ACCES® provides excellent passive attenuation, reducing damaging noise by an average of 30 dB when used in conjunction with military-standard helmets and headsets. The technology not only surpasses legacy systems in terms of safeguarding hearing, a top Department of Defense priority, but also provides superior voice communications clarity. Having already received the safe-to-fly designation needed for use in fighter and bomber aircraft, the newly patented ACCES® is on track to help the Air Force better protect personnel hearing and thereby minimize the substantial long-term costs of treating noise-induced hearing loss.

For more information contact afrl.rh.tech.info@wpafb.af.mil • (937)255-3814

IVAN [the] Not So Terrible for Mundane /Risky Routines

A successful demonstration of unmanned air/ground robotics and collaborative command and control/integrated defense practices proved the viable use of the lab's Immediate Visual Assessment and Neutralization (IVAN) unmanned ground vehicle for maintaining perimeter security. The vehicle was actually one of several AFRL technologies validated during the Vandenberg Air Force Base, California–based event; also demonstrated were the Vigilant Spirit Control Software (VSCS) and the Bat 3 and Unicorn unmanned air vehicles (UAV). The showcased technologies—namely, IVAN, the UAVs, the VSCS-based ground control station, and the various control and decision algorithms needed for the ensuing, operator-managed activities—all performed well in the simulated mission environment. In fact, their seamless integration reflected the type of mission-level synergy achievable by combining not only individual unmanned assets but the collective information gathered and used for accomplishing specific tasks.

AFRL's Airbase Technologies Division is the Air Force's (AF) lead organization for the research and development of advanced fixed and deployed airbase capabilities in force protection, infrastructure, and homeland security. The technologies provided enable nonstop AF readiness, peacetime training, and rapid-deployment missions and operations. The division's Robotics Research Group contributed the IVAN technology for the demonstration. A small, multirole unmanned ground vehicle capable of integrating lethal and nonlethal payloads for mission support, IVAN (as directed) can follow waypoint routes, avoiding collisions along the way, or allow an operator to steer the vehicle. While operators also maintain the manual capacity to manipulate robotic arms and weapons, IVAN's chief purpose is to save time and trouble by automatically performing the repetitive—and often dangerous—tasks of protecting critical assets; performing routine patrols; and responding to, investigating, and neutralizing threats to critical resources.

Subsequent to this positive demonstration outcome, AFRL fielded a request to demonstrate, test, and evaluate its unmanned systems during Air Force Global Strike Command's Mighty Guardian exercise, which tests AF, Navy, and overall Department of Defense requirements for the protection of nuclear resources.

IVAN

The GAO report commending AFRL's Phase III SST SBIR involvement is entitled "SPACE ACQUISITIONS – Challenges in Commercializing Technologies Developed Under the SBIR Program."

GAO Lauds Success of Standard Space Trainer SBIR

A US Government Accountability Office (GAO) report extolled AFRL contributions to Small Business Innovation Research (SBIR) towards an integrated satellite operations trainer. The Phase III work—which produced the Standard Space Trainer (SST)—holds acclaim as an acquisition success story due to its value-added technology outcome and the growing institutionalization of the SST enterprise within the space community. Several notable events with respect to the SST effort are the (1) successful completion of SST Version 2 Simulation Certification by 50th Space Wing instructors/evaluators and Headquarters Air Force Space Command personnel via the new SST Integrated Training Center at Schriever Air Force Base, Colorado; (2) imminent migration of SST architecture from Windows XP to Windows 7 (32- and 64-bit); and (3) impending incorporation of the Wideband Global Satellite Communications system—sometimes called the Wideband Gapfiller Satellite system—into the SST.

The SST implementation culminates work commenced with the Department of Defense's 2008 award of a Phase III contract to SBIR partner Sonalysts, Inc. The project was a response to the growing need for an integrated, simulation-based operator training and rehearsal capability—specifically, one enabling satellite system ground control, given the expectation that future generations of military satellites would use one common ground system to operate multiple satellite constellations. Accordingly, the end-product SST enables satellite operators to experience relevant instructional simulations involving their virtual control of multiple satellite systems via a mechanism similar to a video game console. Because it leverages simulations capable of mimicking the behavior of common military satellites, subsystems, spaceflight, orbital mechanics, and satellite operations, the SST approach supports diverse instructional needs, facilitating independent qualification, unit qualification, crew, and other training types.

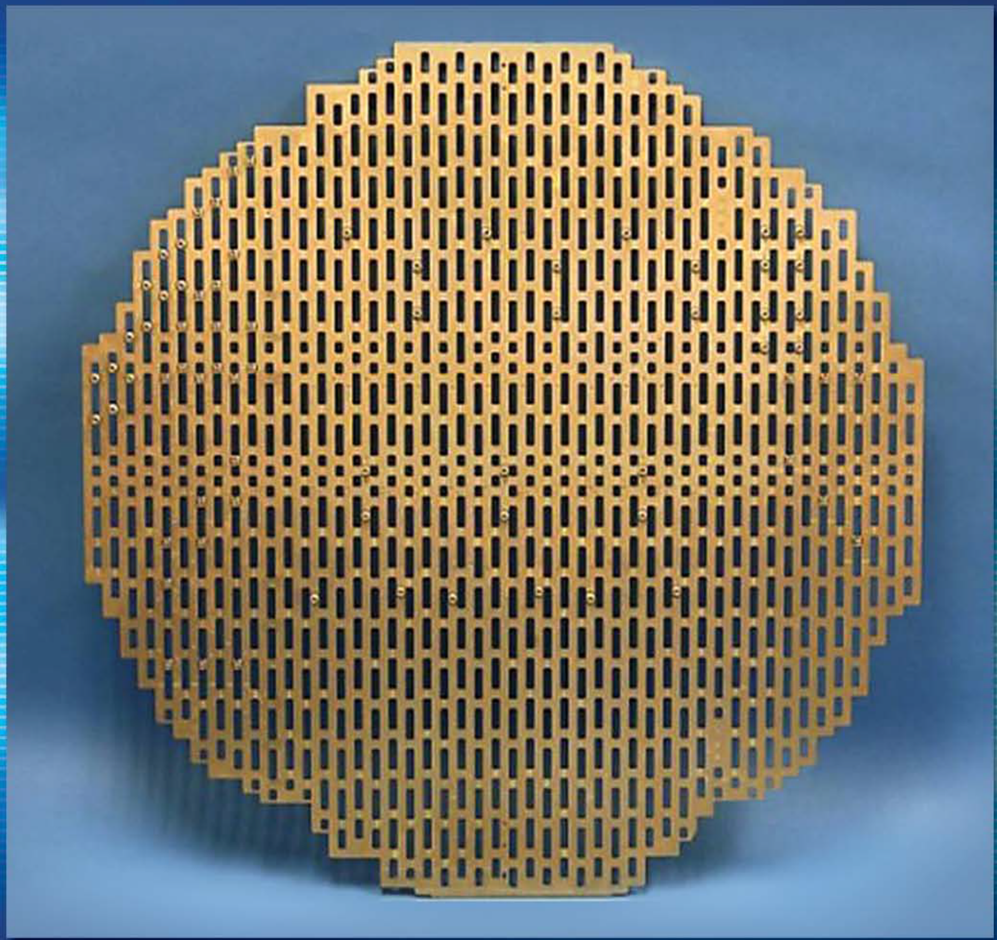
The SST's many advantages include flexible instructor control features, increased instructor and student productivity, quick setup, and lower training costs. The system permits a single instructor not only to monitor—and provide targeted instruction for—up to six students but also to alter any event(s) throughout a given training scenario. Reports from the 533rd Training Squadron, which evaluated the SST, further indicate that its implementation has greatly reduced instructor manpower requirements and improved student evaluation productivity.

ManTech Inputs Lower AESA Cost

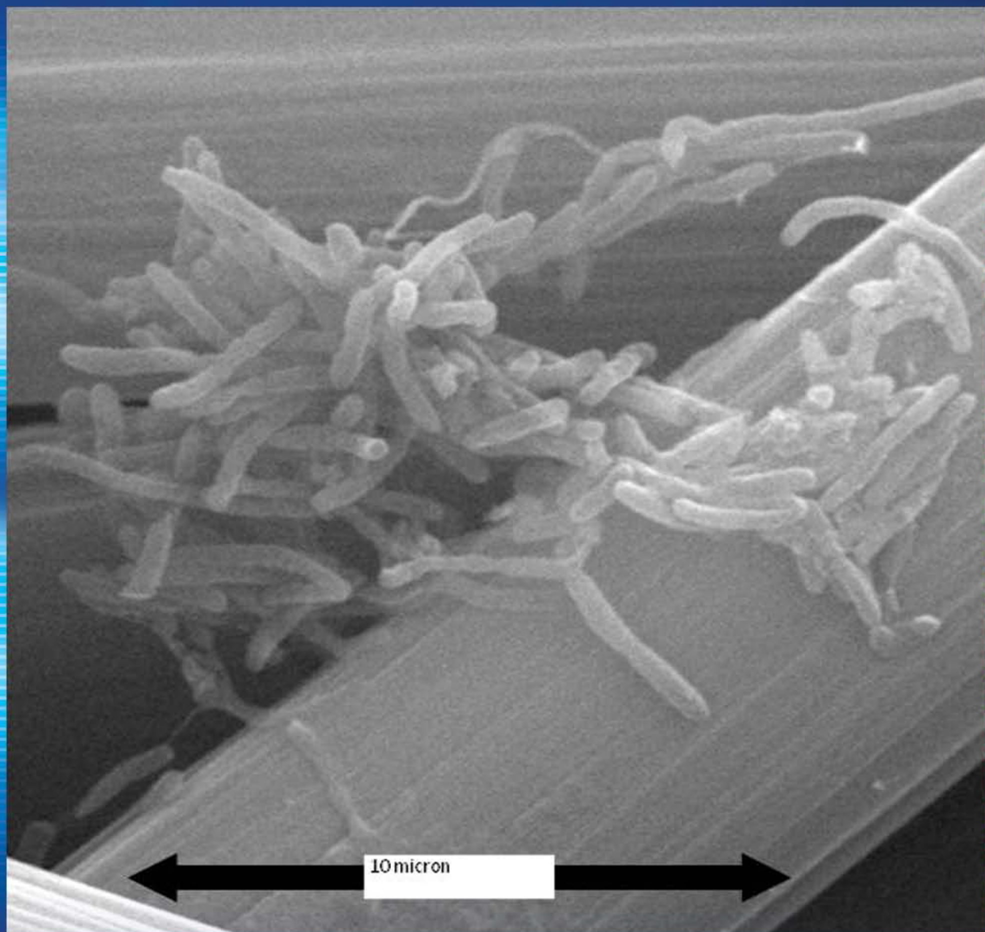
AFRL Manufacturing Technology (ManTech) engineers are engaged in a multiphase program addressing challenges related to the manufacture of Active Electronically Scanned Array (AESA) radar systems, which provide warfighters better performance and reliability over traditional, mechanically scanned and passive arrays. AESA fabrication is an ideal ManTech investment because each system comprises hundreds of complex—but identical—transmit/receive modules. Given the Joint Strike Fighter program's planned production of AESA radars by the thousands, an improved manufacturing approach promises tremendous benefits. Specifically, the ManTech enhancements are likely to generate an overall life-cycle cost avoidance of $380 million, a prediction that considers both current AESA designs and the numerous such configurations anticipated for next-generation aircraft.

At an estimated cost of $5 million per F-22A radar system, the current expense of AESA-equipped aerospace platforms is exceedingly high. Accordingly, ManTech is leading efforts by Northrop Grumman, TTM Technologies, Unicircuit, and Rogers Corporation to evaluate AESA production in terms of improving yields and reducing labor, assembly cycle time, and cost. The ManTech-led team's process improvements related to antenna masking and demasking; radio frequency (RF) component screening metrics; RF manifold design; power supply, printed wiring board, and circuit card assemblies; and material usage have already generated significant AESA production and implementation cost savings for both the F-22A and the F-35.

The masking/demasking improvement reduces the process from 115 to 56 hrs per antenna, roughly a 48% overall reduction in labor hours per array. The improved metrics tool, which uses an intelligent purging algorithm to better predict test yields at the next-higher-level assembly, reduces RF component screening time by 80% and increases yield by 4%. With respect to RF distribution improvements, the team reduced the number of processing steps and the cycle time for producing an RF manifold; whereas the current design requires 28 (7 lamination, 14 drill, and 7 backdrill) steps and a 20-week cycle time, the enhancement decreases the steps from 28 to 4 and subtracts 4 weeks from the cycle time. In its effort to reduce the number of topside high-voltage circuit card assemblies and increase the efficiency of drain power supply, the team cut the number of assemblies from 5 to 1 and upped the efficiency by 6%. Regarding material usage, the team discovered that copper profile used for RF circuit traces can significantly change the radar's performance. Based on this critical finding and the extensive research ensuing as a result, low-profile copper (which exhibits a surface topography very different from that of the previously used, high-profile counterpart) is now specified on all applications.



RF manifold created in AESA Phase I and Phase A program efforts



Scanning electron microscopy image of Shewanella oneidensis bacterial biofilm associated with a carbon fiber electrode

AFRL/Academia Advance Biological Fuel Cell Technology

Multidisciplinary research performed by AFRL and the University of New Mexico prompted key discoveries in microbial fuel cells (MFC), which are likely candidates both as power sources for microscale devices and as integral ingredients in sustainable wastewater treatment systems. In exploring a range of fundamental and developmental aspects of bionanotechnology and materials science, the team devised new ways of processing the various materials used in the construction of fuel cell electrodes. Incorporating bacteria and enzymes, these new processing methods generate what are essentially biological fuel cell catalysts for energy conversion. The collaborators' well-received research results promise critical gains in advanced materials technology.

In MFCs, microbes convert chemical energy to electrical energy by breaking down organic "fuels" (e.g., sugars, biomass, waste streams) and respire by using the fuel cell electrode as an alternate electron acceptor. Inconsistencies in the MFC's natural bacterial populations can hamper this progression, with some populations slow to develop and batch-to-batch variance significant. To address this variability—and, thus, a major experimental hurdle—the team found a way to control the physiological state and size of the bacterial population, first cultivating the cells under well-controlled conditions and then affixing them to the electrode with silica sol-gel via benign chemical vapor deposition. Creating a viable substitute for naturally forming biofilms, the novel process yields an electrochemically active, immobilized bacterial population; mimics the extracellular biomolecules that bind cells in a natural biofilm; and, moreover, avoids the toxicity associated with conventional sol-gel techniques and provides a stable, well-defined microbial community. Though this methodology emphasizes MFCs, it is equally applicable for immobilizing other microorganisms for industrial applications.

In a separate study, the team's findings facilitated electronic connections between fuel cell electrodes and redox enzymes via a process that links multicopper oxidases (MCO) to carbon nanotubes (CNT) such that the MCO catalysts are in a three-dimensional, porous matrix of conductive CNTs and close enough to CNT surfaces to allow electron tunneling. The resultant, biofunctionalized CNT is readily joined to bulk electrode surfaces, providing a practical design for a complete fuel cell.

Title III Targets High-Volume, Automated Ammo Assembly

If successfully completed, a promising Title III effort undertaken by AFRL, US Marine Corps Systems Command, and MAC, LLC, will deliver a fully automated domestic production line that, in turn, establishes a multi-million-unit capacity for manufacturing lightweight ammunition products. The collaborative Defense Production Act–based venture entered its final qualification stage in September 2010. The positive outcome anticipated for this last project phase will yield military-grade ammunition casings made with high-performance polymeric materials that offer significant weight reduction without compromising weapon system effectiveness.

Lightweight ammunitions—cartridge cases, in particular—account for a large portion of the overall weight the modern warfighter must carry. In many instances, carried ammunition far outweighs the related weapon system, primarily because conventional cartridges consist of heavy, metallic-based materials such as steel, copper, aluminum, or brass. Based on their lower weights (and higher corrosion resistance), polymer materials offer a desirable alternative to these and other metals traditionally used in the production of ammunition cartridges. Though the ammo retains a metal base and extraction ring, the additional polymer materials selected for use in the lightweight casings have demonstrated exceptional mechanical strength, ductility, hardness, and scratch resistance, as well as good transparency and ballistic performance in preliminary testing. Their amorphous nature assures easy processability and formability, along with considerable chemical resistance and damage tolerance. Importantly, thermal stability and melt processability are key characteristics required by the Department of Defense (DoD) for casings.

Not only do weight-reducing technologies enable warfighters to carry larger quantities of ammunition, they improve battlefield mobility and survivability. They also decrease the logistical footprint of military operations by facilitating the delivery of more ammunition at the same—or lower—shipment cost. Other potential benefits could include better weapon accuracy, prolonged weapon life, and lower weapon fabrication cost. In order to achieve the program goal of developing the fully automated, multi-million-unit production capability, the team has concentrated on factors such as building construction, equipment procurement and installation, and product design and testing. Facility construction was complete as of March 2009. Production of a lightweight .50 caliber ammunition prototype for DoD test and evaluation is under way, with the assembly line capable of producing one million rounds per year. Live-fire demonstrations of these prototypes indicate favorable results. Design evaluation continues as part of optimizing the product and achieving further weight savings, and full-qualification testing will determine whether the ammunition fulfills form, fit, and function requirements of the warfighter.

.50 caliber lightweight ammunition

AGWT-based WFOV perspective

Projecting a Better View of Urban Warfare

Given that unconventional warfare, including combat in urban environments, has unorthodox challenges, AFRL munitions experts are researching a biologically inspired technology known as optical flow to help warfighters succeed in these cityscape battle scenarios. The novel technique uses multiple wide-field-of-view (WFOV) sensors to detect object motion, enabling warfighters to derive weapon movement in the scene. In this capacity, optical flow can assist soldiers in maneuvering the specialized weaponry that aids their navigation of cluttered-terrain settings.

Urban warfare calls for smaller weapons that operate at low altitudes (in the skyscraper canyons of the city). Many current systems rely on Global Positioning System (GPS) technology for navigational purposes, but since GPS is often blocked in these chaotic backdrops, AFRL is examining WFOV sensing as an alternative, potentially more reliable tool for weapons navigation in the urban jungle.

To test the new sensors, AFRL developed a WFOV capability in the Advanced Guided Weapons Test Bed (AGWT). The system consists of a 4 m diameter dome; nine, 1400 x 1050 @ 2400 lumen DLP [digital light processing] projectors; and a commercial warp blend solution. The resultant WFOV projection produces scenes of 240° horizontal and 135° vertical dimensions. Operations began in January 2010 with parametric performance studies of a Small Business Innovation Research–developed WFOV sensor from Centeye, and the AGWT facility will begin hardware-in-the-loop testing in late 2010.

DISCOVERY

Micro AVIARI, Big Results

In a May 2010 ribbon-cutting ceremony, AFRL launched the Micro Air Vehicle Integration and Application Research Institute (µAVIARI) Indoor Flight Test Laboratory, the new $1.5 million facility dedicated to the advancement of Micro Air Vehicle (MAV) technologies.

The Indoor Flight Test Laboratory is the cornerstone of the µAVIARI, a facility that incorporates four distinct MAV development labs into one building. In addition to the Indoor Flight Lab, the µAVIARI includes the Unsteady Aerodynamics Laboratory, the MAV Fabrication Laboratory, and the Flapping-Wing Bench Test Laboratory. These labs will enable scientists to research, design, fabricate, and test MAVs from start to finish. They also allow for the separation of airframe development from sensor, communication, and payload development, meaning that these technologies can be developed independently and simultaneously.

MAVs are an emerging technology for the urban battlefield. These flight vehicles—less than 2 ft long and potentially as small as a dragonfly—are designed for entering and loitering in urban settings virtually unnoticed, a quality enabling them to perform missions too difficult or dangerous for troops. The Indoor Flight Test Laboratory allows researchers to simulate an urban environment, complete with building fronts and controlled winds. Composed of a test chamber and a separate control room, the Indoor Flight Lab provides a test environment in which researchers can record the motion of MAV flight using a Vicon® Industries–developed camera system. Using the same type of technology employed by video game developers to animate human beings, reflectors placed on MAVs enable the cameras to track position and orientation of the vehicle with an accuracy of approximately 1 mm.

Members of the AFRL ribbon-cutting committee begin the May 2010 ceremony launching the lab's new Micro Air µAVIARI Indoor Flight Test Laboratory.

Eglin "Steels" the Show

Bunker-buster munitions rely on the newly validated Eglin Steel composition. Its upcoming use in the BLU-122 restart will likely save $11.3 million over the warhead's scheduled 3-year production run, and its feasible commercial use could spell additional revenue for munitions programs.

An improved version of Eglin Steel—a strong but inexpensive steel developed by AFRL for next-generation bunker-buster munitions—demonstrated reliable superiority over conventional warhead steels when employed against concrete targets. Conducted by the Air Armament Center (AAC) and 679th Armament Systems Squadron as part of the joint AFRL/AAC Eglin Steel Producibility Enhancement (ESPE) program, the recent demonstration involved six sled track tests of penetrators constructed of Eglin Steel. The successful test results not only elevate the novel steel to Manufacturing Readiness Level 8 but qualify a half-dozen different manufacturers for its warhead-based production.

Augmenting the performance benefits of this high-strength, low-alloy material is its sizeable cost advantage: the price of Eglin Steel is just 35% that of the steel alloys traditionally used for munitions. This difference arises from the necessity that conventional materials be formed using high percentages of alloying elements (e.g., nickel and cobalt)—a composition that promotes penetration survival/mechanical performance but dramatically increases expense. It was in the pursuit of alternatives to such high-alloy, high-dollar compositions that AFRL originally developed Eglin Steel in 2000. Though crafted specifically for munitions applications, this early composition did not dependably exhibit mechanical properties meeting established thresholds for strength and toughness (as demonstrated during initial production of the BLU-122 warhead). With warhead production thus halted after only a year, the ESPE program arose to address the steel's notable performance issues. To remedy the problem, AFRL/AAC researchers worked with six steel manufacturers to incorporate production methods that, by leveraging lab-developed heat treatment and quenching schedules, would reliably produce—and thereafter reproduce—the desired composition. Ultimately, this approach facilitated the establishment of multiple vendors—and, in turn, a diverse range of viable methods—for producing a steel that ultimately exceeded BLU-122 program requirements.

As part of ESPE validation efforts, each of the six manufacturers completed three heats, collectively generating nearly 1 million pounds of steel. From this material, the team first formed and analyzed more than 2,200 samples and then produced 18 BLU-122 warheads. The recently demonstrated, flawless performance of six of these warheads translates to a newfound confidence in acquiring uniform Eglin Steel—through numerous manufacturing sources, with necessary strength and toughness, and at substantial savings.

By eliminating production inconsistencies and thereby ensuring sound material properties, the ESPE effort provided a newly confirmed capability for defeating modern, hard, deeply buried targets. Accordingly, Eglin Steel is the material of choice for the BLU-121; the material select for the BLU-122's production restart (Fiscal Year 2013); and, further, the paramount material under consideration for Army, Navy, and civilian applications.

For more information contact afrlmark@eglin.af.mil • (850)882-3009

Research Continues on Secure, Mobile, Quantum Communications

AFRL's Dr. David H. Hughes leads a lab-funded research team in the investigation of long-distance, mobile optical links imperative for secure in-theater quantum communications. The Rome, New York-based team is conducting high-data-rate experimentation using an optical laser link, a tool that exploits the quantum noise of light to achieve higher security. The system uses adaptive optics for transmitting high-data-rate video and audio signals over long distances.

Meanwhile, AOptix Technologies, a developer of ultra-high-bandwidth laser communication solutions for government and commercial markets, has joined forces with AFRL to flight-test the system at 10,000 ft in order to evaluate the performance of its high-altitude, air-to-ground, quantum communications links. Until now, the challenge associated with free-space optical links, which use fiber optics for transmission, has been atmospheric turbulence. Transmitting information through turbulence creates distortions analogous to the muddled, fuzzy effects of viewing light reflected off a distant, twinkling star. Overcoming this obstacle requires the use of adaptive optics to rectify the distortion and generate a better quality signal.

Dr. Hughes and his team have already established a distortion-free optical link at a distance of 35 km for stationary and flight test situations. The next flight test will aim for increased altitudes in order to demonstrate further air-to-ground distances. In addition to beneficially impacting operational aircraft capability, this new technology may even contribute to saving military lives, given its capacity for enabling real-time access to ultra-high bandwidth intelligence, surveillance, and reconnaissance data from various manned and unmanned airborne platforms.

AFRL's Dr. Hughes leads a lab-funded research team in the investigation of long-distance, mobile optical links imperative for secure in-theater quantum communications.

(Pictured top) Dignitaries attend the MSSC dedication of "Mana" at the MHPCC's DSRC. (Pictured bottom) AFRL workforce members pose "Mana" in the background.

AFRL "Mana"ges New Supercomputer Dedication

AFRL's Maui Space Surveillance Complex (MSSC) recently dedicated a new supercomputer at its Maui High-Performance Computing Center's (MHPCC) Department of Defense (DoD) Supercomputing Resource Center (DSRC). Dubbed "Mana," the Hawaiian word for "power," the new computer doubles the facility's computing power and establishes itself as the fastest such device in the DoD. The Dell-platform-based system processes at a rate of 103 teraflops (103 trillion floating point operations per second), greatly expediting the delivery of computationally derived solutions to the warfighters who need them.

As a national resource-chartered center supporting a diverse base of DoD and other government users, the MHPCC DSRC facilitates a broad range of collaborations focused on complex computational work. Mana, at 13,000 times the power of the first-generation device installed at the facility in 1993, leverages world-class technologies to meet the ever-increasing requirements of supercomputing in this regard.

The DSRC is actually one of the DoD High-Performance Computing Modernization Program's (HPCMP) six supercomputing resource centers. With a mission to accelerate the development of advanced defense technologies for transition as superior warfighting capabilities, the HPCMP strives to exploit and strengthen US leadership in supercomputing, communications, and computational modeling. The introduction of Mana will enable the MHPCC DSRC to allocate more than 70 million computational hours annually to HPCMP-related activity.

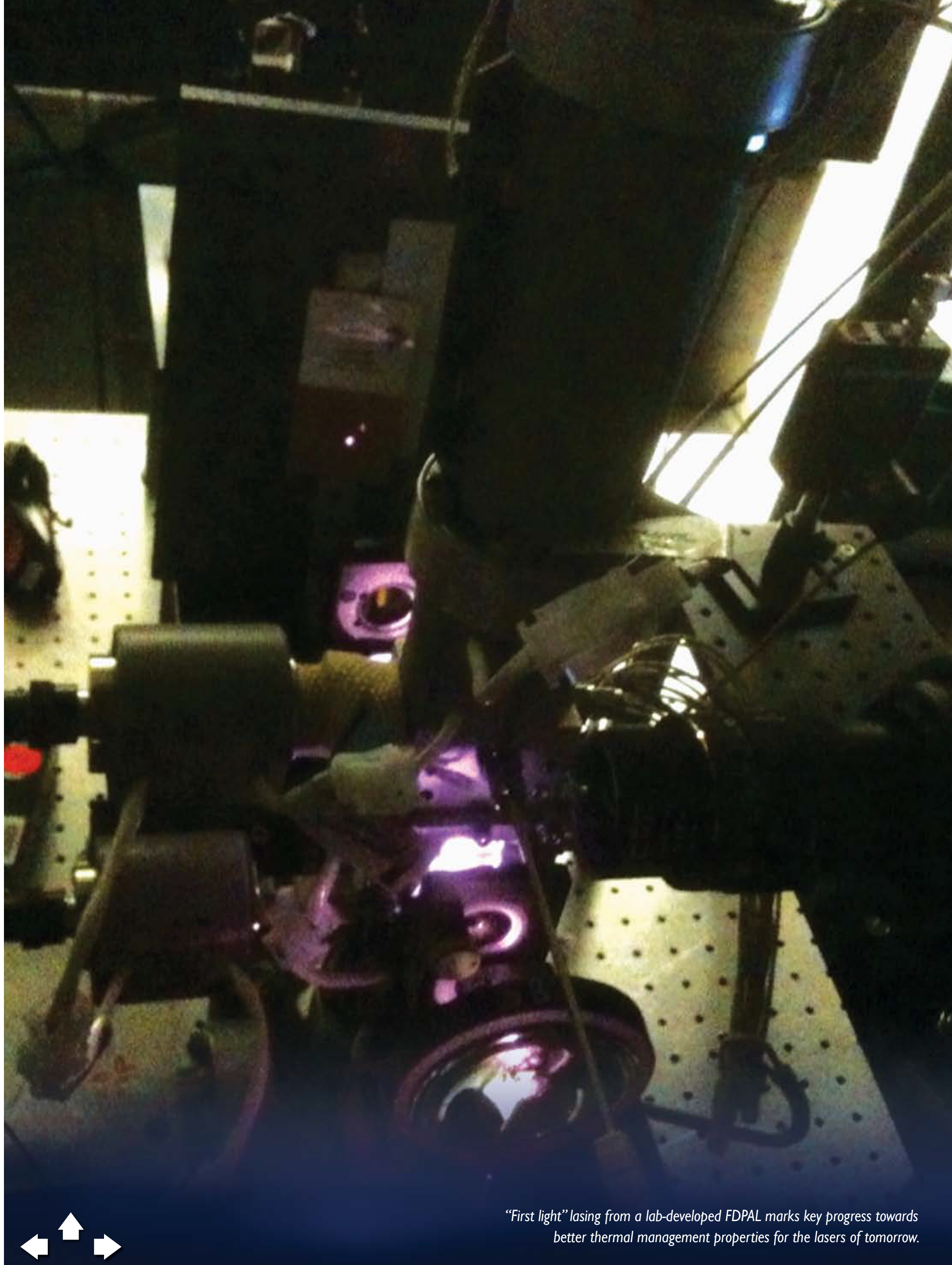
For more information contact afrl.public.affairs@kirtland.af.mil • (505)846-1911

Go With the Flow: Novel Diode-Pumped Alkali Laser Achieves First Light

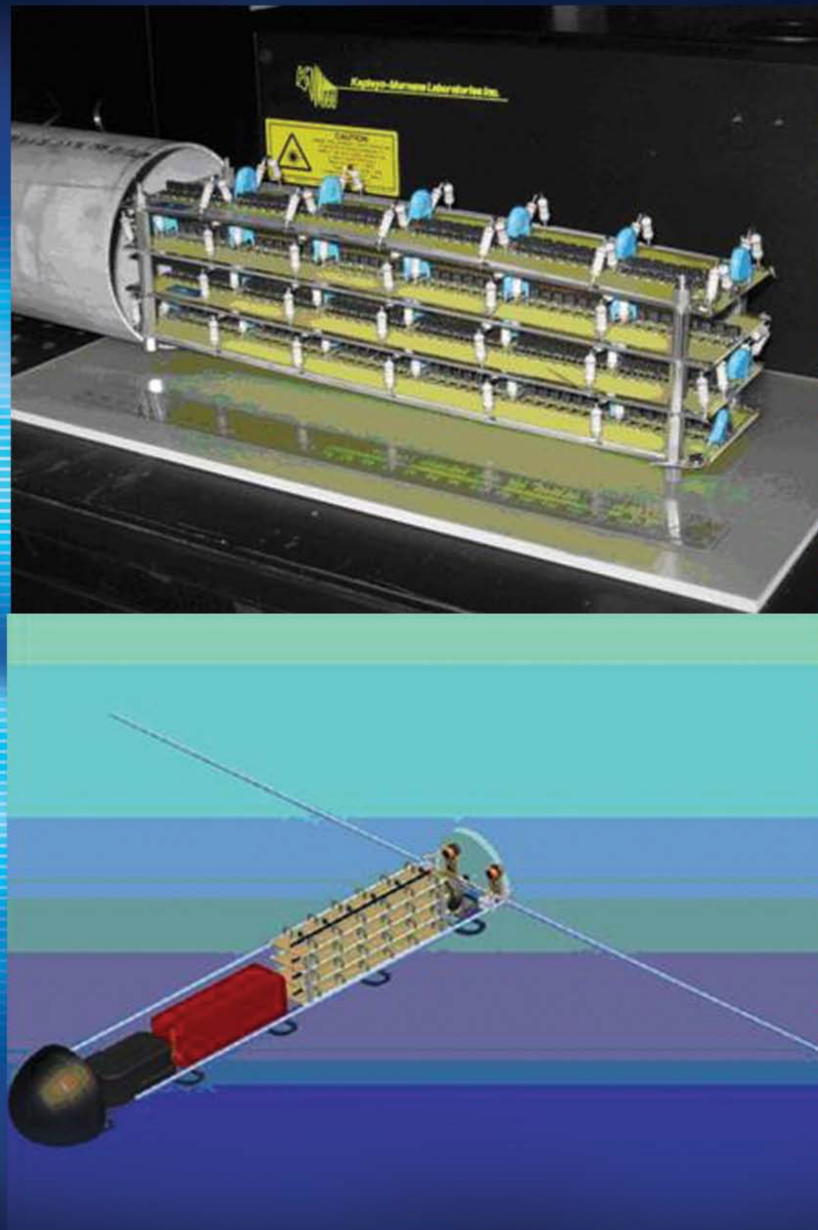
AFRL's achievement of "first light" lasing from a new type of diode-pumped alkali laser (DPAL)—namely, a flowing DPAL, or FDPAL—marks a significant first step in the direction of high-power laser systems exhibiting the thermal management characteristics needed for future military applications. The lab's successfully designed, developed, and demonstrated FDPAL configuration enables the thermal management system to be decoupled from the lasing cavity—which, in turn, improves the capacity to remove excess heat from the system without sacrificing performance.

DPALs, which themselves represent a relatively new class of lasers, are essentially gas lasers that leverage the advantages of both gaseous gain media and solid-state pump sources. Early DPAL demonstrations relied on the use of gain media in static cell configurations, an approach that effectively limits the amount of heat deposited into a system before thermal effects begin to degrade performance. By incorporating flow technology into the standard DPAL design, AFRL's FDPAL innovation achieves the same effect: removing heat from the gain medium and thereby improving overall beam quality.

Though gas/chemical and solid-state lasers offer a powerful range of capabilities, each variety has its shortcomings. For instance, because gas lasers depend on a chemical reaction to excite their gain medium for lasing, they come with a chemical storage requirement and the burden of the accompanying logistics trail. DPALs (including AFRL's FDPAL) address this issue by accomplishing their lasing via electrically driven diode pumps—a plus traditionally associated with solid-state laser sources. Meanwhile, solid-state lasers have problems with thermal management—specifically, with heat buildup that, by detrimentally affecting the lasing medium, ultimately degrades beam quality. The recently demonstrated FDPAL overcomes this problem by means of its built-in flowing medium, which carries surplus heat away and thereby produces better beam quality.



"First light" lasing from a lab-developed FDPAL marks key progress towards better thermal management properties for the lasers of tomorrow.



Pictured (top) is POC third-generation SSMM generator, capable of generating maximum power of 50 kV x 100 A and fitting in a 4" diameter tube. Pictured (bottom) is a rendering of the generator as an EMI source in an airborne nonlethal weapon equipped with a nose cone for soft landing

Mini Generator "Marx" the Way to Directed Energy Advances

Working under Small Business Innovation Research (SBIR) contract to AFRL, Physical Optics Corporation (POC) developed a novel generator technology of import to improvements sought for Air Force (AF) airborne and ground-based radar and high-power microwave (HPM) systems. Applying its unique expertise as a technology-based small systems integrator, including vast experience with related electronic and high-voltage technologies, the company created the Solid-State Mini-Marx (SSMM) generator—a lightweight, pulsed-power, miniature device that surpasses existing Marx generator technology.

The small Marx generators currently in place, though presently the AF's lightest means for achieving high voltages, fall short of desired performance requirements: 150-250 kilovolts (kV) damped sine wave between 100 MHz and 1 GHz. While constructing an array of several Marx generators provides a workaround, the preferred length of 12" and diameter of 3" renders such an assembly less than ideal.

Conversely, at 11.5" long and 4" in diameter, POC's SSMM provides a 24-stage solution. Specifically, the device comprises a 24-stage array of avalanche bipolar junction transistors configured as an ultrafast solid-state switch. A single trigger on the first transistor of the first stage fires the sequenced switches of all subsequent stages like a traveling wave. This setup, which completely eliminates jitter problems, routinely achieves nanosecond high-voltage impulse. Rise times of 2.5 ns and 100 MHz are typical, as are intermediate voltages of 51.6 kV-peak peak (pp—limited by the high-voltage probe capability) at the 12th stage and expected voltages exceeding 100 kV-pp at the 24th stage.

This SBIR-enabled technology could conceivably impact a substantial number of systems serving government and commercial concerns alike. An application of immediate AF interest involves the SSMM's use as an electromagnetic interference(EMI) source in a nonlethal weapons system, given its capacity to produce 50 kV amplitude (100 kV-pp), 100 MHz sine waves at 10 A and meanwhile accommodate an 18 V battery, a 4 kV-30 mA DC/DC power supply, and a 100 MHz dipole antenna. Included among possible AF applications of the future is the generator's use in modulating klystron microwave sources capable of emissions topping even 10 GHz. The breakthrough technology also promises exceptional utility in the area of ultrabroadband radar development and will likewise prove useful for enhancing HPM capability, once subnanosecond rise times and, in turn, pulses in the gigahertz range become a reality.

For more information contact afrl.public.affairs@kirtland.af.mil • (505)846-1911

AFRL Untiring in Fatigue Countermeasure Pursuits

AFRL and industry partner Kettering Innovation Center (KIC) are conducting state-of-the-art research investigating why some individuals are resistant to fatigue while others are not. The team's latest effort involves functional magnetic resonance imaging (MRI), the results of which will aid in determining whether substantial differences exist in the brain activity patterns of wakeful people compared to those who have trouble staying awake. In order to establish a representative database of Air Force (AF) test subjects, KIC will perform the MRIs—more than 100 total—both on rested and on sleep-deprived individuals.

A Cooperative Research and Development Agreement between the AF and Kettering Health Network is facilitating the work, with Siemens Medical Solutions providing its latest imaging technology at KIC. Also participating are the University of Dayton Research Institute and Qbase, a data management and analytics company charged with securing funding for further studies.

Overseeing the endeavor is Dr. J. Lynn Caldwell, a top fatigue countermeasures expert at AFRL. Dr. Caldwell stresses that while scientists can already identify people who are resistant to fatigue versus those prone to its effects, much remains to be discovered regarding the causes underlying such distinctions. Accordingly, ongoing research is geared towards learning whether a particular chemical is involved. This recent activity actually marks the second time Dr. Caldwell has participated in research using MRIs. The first instance was in 2004, when a study entailing brain scans of AF fighter pilots revealed this community's fatigue resistance as higher than that of the general civilian population. That earlier milestone research now serves as the foundation for the present undertaking.

Unlocking the mystery of why some individuals can stay awake and perform well on a small amount of sleep will ultimately help experts develop courses of action to assist people in overcoming fatigue. Consequently, the results of this—and future—fatigue countermeasures research stand to benefit military and civilian interests alike.

Technologist performs fatigue research on a test subject from Wright-Patterson Air Force Base, Ohio.

Second Lieutenant Greg Fertig, AFRL SP project manager (left);
Lieutenant Colonel Matt Martin, ACC Predator/Reaper operations branch chief (right)

No Substitute for Lab's Ongoing "SPort": Surrogate Predator Support

Having provided ongoing support to the Surrogate Predator (SP) program since 2008, AFRL delivered the second of two requested surrogate aircraft earlier this year. The SP program provides the Air Force (AF) with simulated Predator aircraft that, when employed with other AF assets in Green Flag exercises, enable actual Predators to continue critical real-world operations.

Integrated with Army combat training centers at Fort Polk, Louisiana, and Fort Irwin, California, SPs provide close air support along with intelligence, surveillance, and reconnaissance (ISR) mission support during Green Flag deployment training exercises. This win-win program saves Air Combat Command (ACC) $1.5 million per year in contracted ISR support, while providing the most cutting-edge ISR capabilities available. It also enables the Army to practice using the aircraft without removing Predators from deployed locations and, meanwhile, provides AFRL a platform for technology integration and warfighter training insight.

In December 2008, AFRL's Standoff Intelligence Detection (SID) team responded to ACC's expressed need for surrogate Predator aircraft. Leveraging an existing contract and the subject-matter expertise of the SID team, AFRL's Optics Division was able to build two imaging turrets and install them on Civil Air Patrol aircraft. Prior to the SP program effort, ACC relied on expensive contracted ISR support when Predators were recalled for higher-priority operations. Based on the enormous utility of the first two surrogates delivered, ACC has requested a third surrogate Predator for Green Flag exercise use.

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AFRL Engages India's IT Community

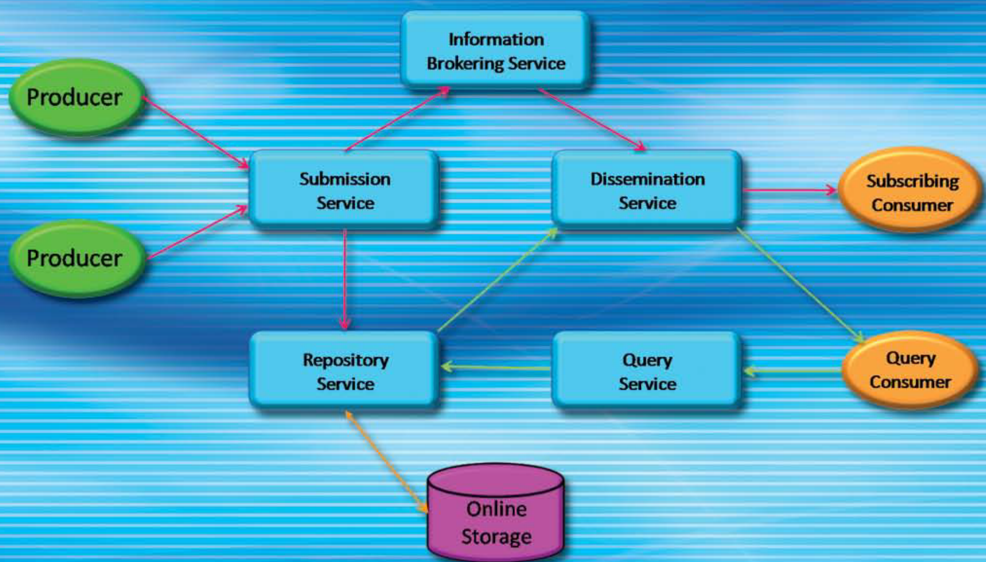
Information technology (IT) outsourcing has spurred the founding of an Indo-American communications—or IAMCOM—forum dedicated to researching functionalities critical to the increased failure resiliency of systems operations. With support both from the AFRL Air Force Office of Scientific Research (AFOSR) and Asian Office of Aerospace Research and Development (AOARD) and from the Office of Naval Research-Global (ONRG), AFRL's Dr. Kevin Kwiat worked with Professor Kaliappa Ravindran to coordinate the Workshop on Intelligent Networks: Adaptation, Communication, and Reconfiguration—the fourth consecutive IAMCOM workshop event.

IAMCOM deals with assuring communica-tions between application endpoints in a distributed system. It synergizes three research subareas: adaptation of system operations to network resources and environment-related conditions, reliability of communications between endpoints in the presence of failures, and execution of self-reconfiguration at various system levels to ensure robust performance. Underscoring IAMCOM's importance is the attention given the initiative by prestigious organizations such as the Institute of Electrical and Electronics Engineers, which publishes annual IAMCOM workshop proceedings.

The site of IAMCOM 2010, held in early January, was Bangalore, India—the US' leading IT importer. Although compulsory Department of Defense personnel travel restrictions prevented Dr. Kwiat from joining his coorganizer at the event, he was able to assist via proxy, given his role as adjunct professor of computer science at the State University of New York Institute of Technology. Many of his former students are now professionals in India's IT industry and, based on their connections to Dr. Kwiat, have emerged as IAMCOM volunteers, lending local assistance towards the workshop's successful completion.

Because AFOSR and ONRG share common technical projects, such as airborne networking, both organizations have deemed the IAMCOM theme mutually beneficial. IAMCOM principles have significance for AOARD and ONRG as well, considering that both conduct international information assurance and intelligent networking forums and symposia to bolster awareness of—and protection against—information threats and attacks. IAMCOM seeks such awareness and protection, but directs these goals more broadly towards joint Indo /US IT development.

IT outsourcing prompted an IAMCOM (logo pictured) forum geared towards increasing system resiliency in the face of information threats and attacks.



AFRL's Phoenix information management capability provides DoD organizations and contractors a mechanism for storing, filtering, brokering, routing, and disseminating information to edge consumers.

The "RISE" of Phoenix

AFRL's Enterprise Information Management Branch (RISE) is pleased to report that version 1.1.7 of its Phoenix information management (IM) services system has been released for use by Department of Defense (DoD) researchers, both internal and external. Phoenix provides a collection of IM services facilitating the efficient storage, filtering, brokering, routing, and dissemination of information to edge consumers. In addition to providing publish-and-subscribe and query capabilities to clients and systems, Phoenix supplies specific services addressing the management and dissemination of streamed information. Further, a recently developed cursor-on-target router service that is fully integrated with Phoenix IM technology is also now available. As with the Joint Battlespace Infosphere implementations preceding it, Phoenix is free and available upon request to all DoD organizations and contractors working under DoD contract.

The Air Force (AF) and the DoD have been moving towards a network-centric concept of operations for several years. The advent of service-oriented architecture (SOA)–based systems has increased the likelihood of actually implementing the conceived overarching Global Information Grid. SOA-based systems group functionalities around business processes and expose them as packaged, interoperable services. These services enable applications to exchange data as they perform their individual or collaborative business processing. Collectively, these SOA characteristics provide the perfect blend of rigidness and flexibility needed for effective IM operations.

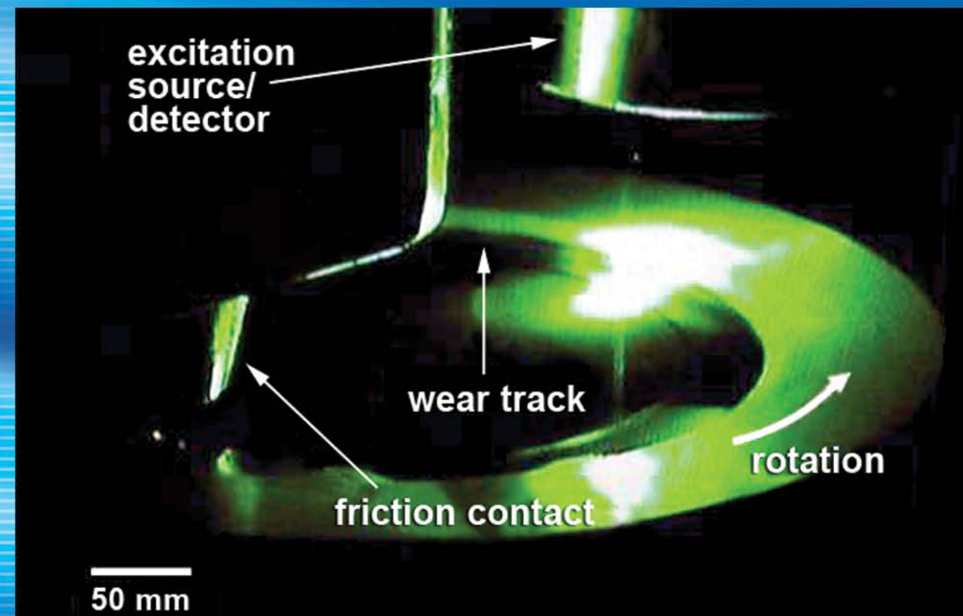
AFRL's pioneering work in the field of IM, particularly that performed since the late 1990s, has largely succeeded in overcoming earlier, Scientific Advisory Board–documented concerns regarding AF shortcomings in the area of systems integration and IM. In this capacity, the success of Project Phoenix exemplifies the lab's ongoing commitment to continuous advancment of leading-edge information technologies. Accordingly, in defining a meaningful SOA-based IM solution—one relevant now and well into the foreseeable future—Project Phoenix has leveraged not only in-house IM knowledge, but the expertise of colleagues and customers as well. Further, various checkpoints throughout the Phoenix development effort have ensured the technology's alignment with respective AF and DoD visions of current and future net-centric operations.

Materials Breakthrough Leads to Automated Component Health Monitoring

AFRL materials scientists developed a Raman tribospectrometer—as well as smart wear-resistant materials for use with the device—enabling *in situ* characterization of such materials at high temperatures. The development is a notable achievement in terms of automatic reporting of wear rates and health monitoring of mechanical components, not only while in place but while in use (i.e., rotating at high speeds or operating in extreme environments). By automating the formerly time-consuming, financially and physically risky manual process for component health monitoring, the new technology will support the creation of coatings and other materials providing optimal thermal and wear protection for Air Force systems.

Facilitating materials assessment during the early stages of systems design, the device instantly identifies surface chemistry during wear testing. Accordingly, it reveals the onset of oxidation or sublimation temperature, the evolution of compound formation, the presence of coating material failure mechanisms, and similarly distinctive factors that can help researchers rely more strongly on measured properties to predict—and thus, avoid—subsequent failures (e.g., coating). Beyond its capacity for surface chemistry evaluation during wear testing, the new device permits the characterization of wear process effects. Further, it helps researchers avoid any misleading results stemming from chemical phases that may develop as materials are cooled to convenient temperatures for handling purposes.

The tribospectrometer consists of a low-power (25 mW) laser directed towards the coating surface; some simple optics; and a basic detector, which analyzes light scattered from the surface. This light serves as a fingerprint for identifying surface chemistry via luminescence phenomena such as fluorescence (in the case of wear sensors) or Raman scattering for chemical species analysis. In addition to reducing the labor and risk associated with traditional component teardown and rebuild, the automatic health monitoring innovation will also direct the lab's development of new lubricant materials designed to provide lubrication in temperature extremes ranging from 77°F to 1800°F (25°C-1000°C) for air and space platforms alike. The system is easily miniaturized and robust enough for use at high temperatures and in other adverse ambient conditions. Consequently, researchers in other laboratories (e.g., University of Florida; University of Leoben, Austria; and several others) are currently reproducing this system for their own use, and funding of a Phase II Small Business Innovation Research project for developing a health monitoring system based on this technology is currently under way.



Pictured here is the instrument in operation, with the laser incident on a wear track created by a ball bearing's contact with a solid lubricant surface rotating at 200 rpm.

The hybrid, high-performance vehicle—which fits in a CV-22 aircraft—provides extended range, exportable power, and configuration flexibility.

Joint Service/Industry Alliance Jams on JAMMA

An AFRL/Army/industry effort successfully addressed unique Air Force Special Operations Forces (SOF) requirements by overseeing the TAC-V company's development of JAMMA, a Joint All-Terrain Modular Mobility Asset that reigns as the world's only armor-ready, four-passenger, hybrid, high-performance, off-road vehicle that can fit inside a CV-22 Osprey aircraft. In addition to addressing this key transportability issue, JAMMA provides extended vehicle range, fuel-related flexibility, exportable power, and configuration adaptability—qualities that support the ever-changing operational demands of diverse SOF missions.

State-of-the-art lithium-ion battery technology and an electric motor facilitate JAMMA's extended range. Thanks to the incorporation of these elements, the vehicle sports a hybrid drive train capable of switching between all-electric, silent mode and hybrid electric mode in order to extend its range through fuel-efficiency optimization. Further enhancing this capability is the engine's capacity to run equally efficiently on either diesel or JP8 fuel. In addition to promoting fuel economy, the vehicle's hybrid driveline can produce continuous exportable power. Meanwhile, JAMMA's modular design is easily reconfigurable to meet the varying requirements of different SOF missions.

The collaboration between AFRL munitions experts and engineers at the Army's Tank Automotive Research, Development, and Engineering Center arose from Air Force Special Operations Command's (AFSOC) need for an easily transportable all-terrain vehicle capable of clandestine operation. Specifically, AFSOC sought a quick and agile, quiet, and easily reconfigurable vehicle compatible with the CV-22 and both internally and externally transportable.

Among the many challenges inherent to delivering these characteristics in a single package were the volume and floor loading limits of the CV 22 cargo bay, which was designed primarily for carrying troops. Despite the abundance of such issues, the team produced a successful prototype vehicle that has already undergone extensive testing and analysis for CV-22 flight certification. The promising results of these JAMMA activities conducted to date have yielded detailed specifications for future production and operational fielding of the technology.

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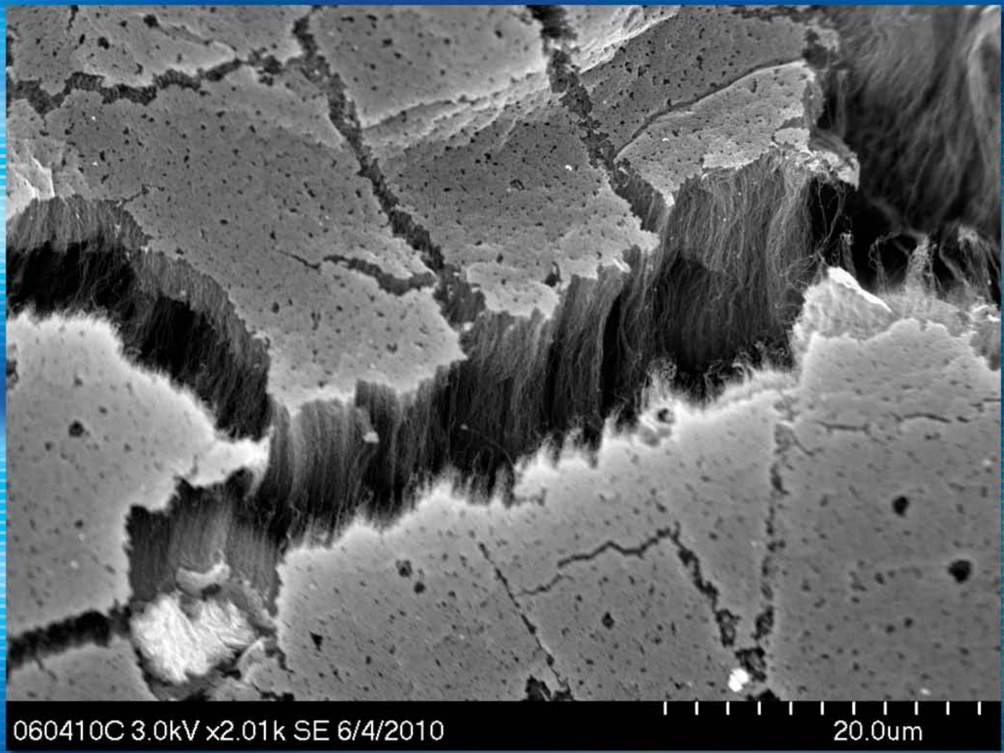
Lab Supplies "Rx" for Carbon Nanotube Growth

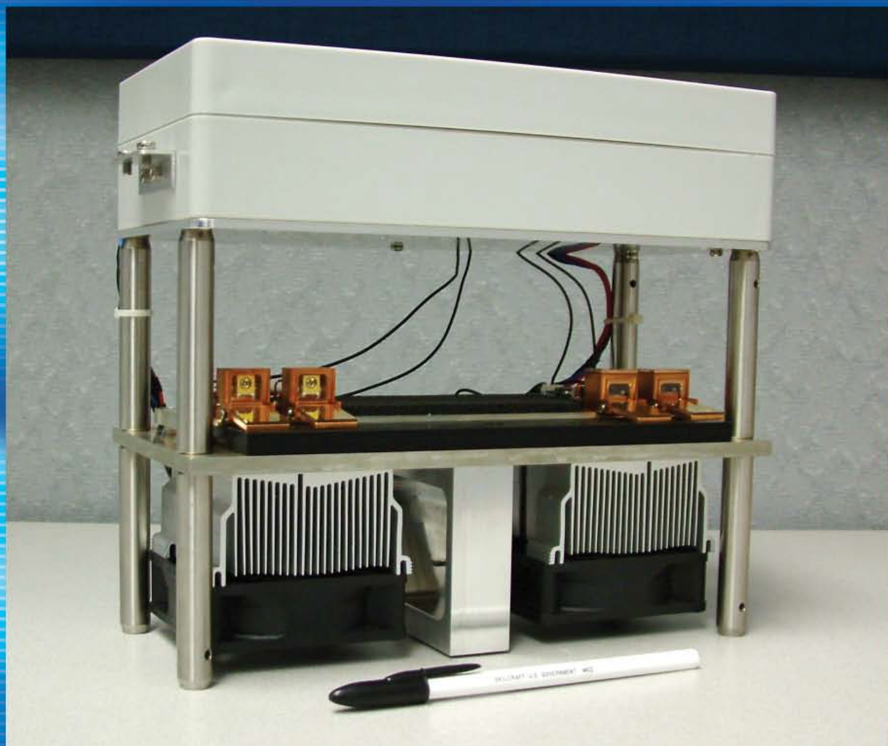
AFRL headed a research team internationally recognized for its groundbreaking discovery of chemical vapor deposition (CVD)-based growth mechanisms for single-wall carbon nanotubes (SWNT), which are key elements for an ever-increasing number of important technical applications. The Materials and Manufacturing Directorate (RX)–led team was the first to connect catalyst changes to carbon nanotube growth mechanisms, a breakthrough expanding scientific understanding of the growth process and subsequently prompting dramatic improvements in SWNT length, yield, performance, and cost.

Specifically, this effort revealed how SWNTs stop growing as a result of catalyst ripening and, consequently, established the role of the substrate in carbon nanotube carpet growth. By inhibiting catalyst ripening, the researchers were able to explain the rapid (10 min) growth of dense carpets of high-purity SWNTs to heights (lengths) up to 2.5 mm. In addition to elevating AFRL's status as a key international contributor to the scientific knowledge of SWNT growth, the finding completely transformed the understanding of nanotube synthesis and resulted in a highly cited, three-paper series on dynamic catalyst evolution.

Carbon nanotubes are cylindrical carbon molecules with novel properties rendering them useful for many applications in nanotechnology, electronics, optics, structures, and other areas of materials science. Initiating CVD-based growth of SWNTs involves preparing a substrate with a layer of metal catalyst particles. The size of these particles dictates the respective diameters of the SWNTs, each of which grows at a specific catalyst site. Scientists have previously been able to produce dense carpets of millimeter-long nanotubes using a super-growth, water-assisted CVD process. While the ultralong SWNTs attained more recently are promising, the creation of such longer structures has historically received little attention and held limited appeal. This lack of enthusiasm was due to insufficient understanding of carbon nanotube growth and kinetics, a knowledge shortfall that inhibited potential applications and precipitated costly, random growth experiments. Of particular concern was the growth termination that occurs once micron-long nanotubes have been achieved. This early-ending nanotube synthesis created process variability, short lengths, compromised purity, and lower yields. Compounding this problem was the equally deficient understanding of carpet growth, itself a complicated process. AFRL scientists responded to these obstacles by first conceiving of the possible "culprit" mechanism responsible for CNT growth termination and then assembling a high-powered multidisciplinary, multiuniversity team to investigate this mechanism.



Scanning electron microscope image of a "carpet" consisting of carbon nanotubes (about 2-4 nm in diameter and 10 μ tall) that grow vertically and terminate collectively. AFRL led a research team that provided the first-ever explanation of early growth termination by the Ostwald ripening phenomenon.



AFRL demonstrated the capacity of laser diode technology to function as a beacon (pictured) for heightening battlefield awareness and decreasing the potential for friendly fire and fratricide.

Laser Diodes Demonstrated as IR Beacon

Ever attuned to the warfighter need for enhanced battlefield awareness and lowered risk of friendly fire and fratricide, AFRL scientists demonstrated the viable use of infrared (IR) laser diodes as an Identification Friend or Foe (IFF) and Positive Identification (PID)—IFFPID—beacon for identifying ground forces from a military aircraft. Conducted as part of the 2009 Tech Warrior Exercise, the demonstration event included aircraft equipped with targeting pods for detecting the ground-based beacon, as well as Joint Terminal Attack Controllers for providing aircraft control.

AFRL has for some time funded the investigation of laser diode technology through the Small Business Innovation Research (SBIR) program. The chief objective of these various SBIR efforts has been to develop high-power IR laser diodes that would, in turn, enable the advancement of technologies such as laser diode pumps; range finders; fuzes; and IR, ladar (laser radar), and semiactive laser scene projectors. Beyond this primary focus, however, AFRL scientists quickly discovered ways to leverage this cutting-edge technology to address the need for an IR beacon.

During the demonstration event, pilots were able to detect and track the ground-based IFFPID beacon to an operationally significant distance. The successful outcome of this demonstration activity moves the technology a step closer to being fielded and thus providing better situational awareness—and consequently, improved safety—for deployed troops.

New Facility a Positive for Positron Spectroscopy Advances

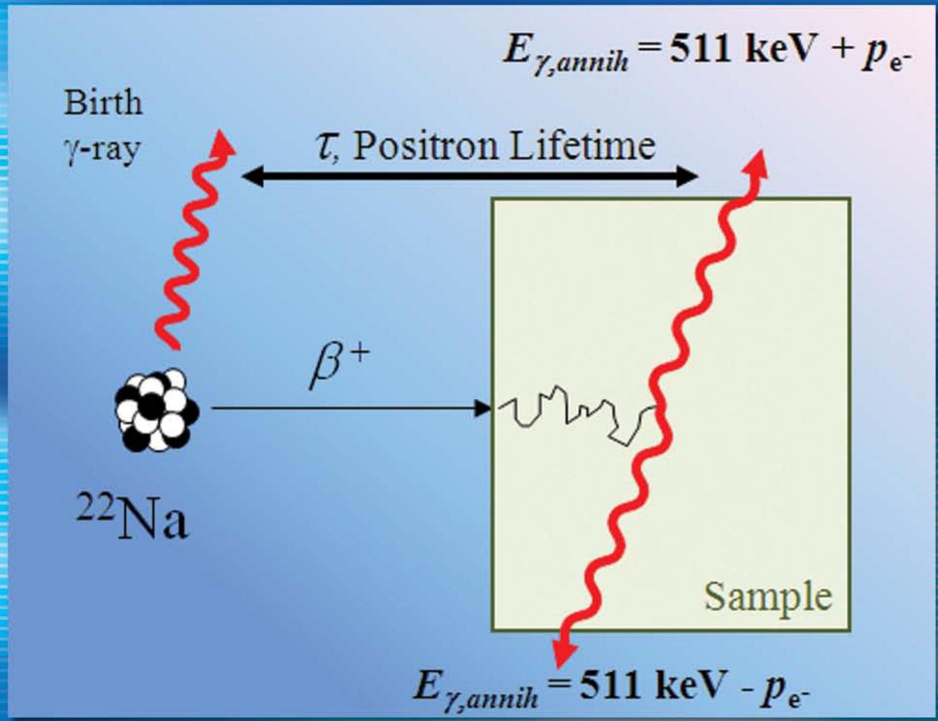
AFRL researchers at Eglin Air Force Base, Florida, demonstrated initial operational capability of a positron spectroscopy lab that promises to shed light on atomic and nanoscale flaws existing in energetic materials, which are critical constituents of insensitive munitions. The new facility—where researchers will have access to Positron Annihilation Lifetime Spectroscopy (PALS) and Two-Dimensional Doppler Broadening of Annihilation Radiation (2D-DBAR) technologies—will facilitate efforts to obtain crucial information regarding the concentration, morphology, and size of the defects and voids found in assorted energetic materials of importance to warfighter capability development.

When a positron (the antiparticle of an electron) enters a material, it tends to localize in open volumes. After a short time, the positron (along with its partner electron) annihilates, producing gamma rays in the process. Using scintillation and semiconductor detectors to measure the time of arrival and precise energy of the annihilation-produced gamma rays enables positron lifetime and partner-electron momentum to be determined. Since the positron is a highly interactive probe, these resulting gamma ray spectra are very sensitive to the size and makeup of defects and voids present in the material. Thus, while researchers have for decades used positrons to nondestructively probe the defect structure of semiconductors, metals, and polymers, they have only recently begun using them to examine energetic materials (explosives, propellants, fuels, and so on).

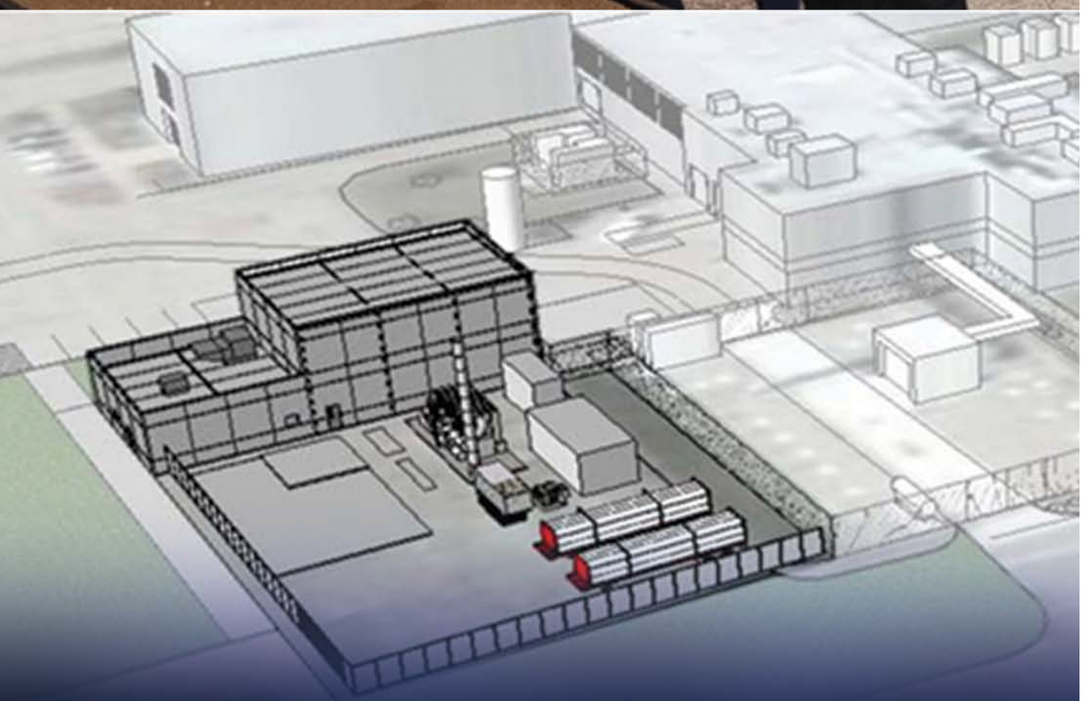
It is well known that the mechanical properties, reaction dynamics, and initiation thresholds of energetic materials are profoundly affected by the presence of defects and voids in those materials. The role that such flaws play at the submicron scale, especially in nanoengineered materials, is unclear. This poor understanding is largely due to the difficulty of probing, in a nondestructive way, such length scales in the bulk. Accordingly, experts anticipate that PALS and 2D-DBAR will prove invaluable in refining energetic materials processing methods, as well as expounding the importance of nanodefects in insensitive munitions development.

The PALS and 2D-DBAR tools represent short-term payoff products precipitated by AFRL's long-term research efforts towards practical positron energy conversion. The newly demonstrated positron spectroscopy lab promoting the use of this technology is unique in the Department of Defense and will undoubtedly serve as a tremendous resource for the characterization of a wide range of materials.

For more information contact afrlmark@eglin.af.mil • (850)882-3009



Shown is a graphical depiction of positron spectroscopy results.



This symbolic excavation (pictured top) at WPAFB initiates construction of AFRL's AAFRF. Pictured (bottom) is the Schematic diagram of AFRL's AAFRF.

Facility to Enhance Alternative Fuels Research

With a ground-breaking ceremony held at Wright-Patterson Air Force Base (WPAFB), Ohio, the Air Force (AF) ushered in a new capability for researching secure, eco-friendly, and renewable fuels. The symbolic excavation marks the start of a significant construction effort that will ultimately yield the AFRL Assured Aerospace Fuels Research Facility (AAFRF), a resource dedicated to advancing the research of non-petroleum-based fuels and fuel feed stocks that can be produced domestically and in quantities sufficient for satisfying Department of Defense requirements. Ideally, these fuel products will also be environmentally sound and noncompetitive with human food production practices.

Once this unique facility is fully operational, a research team comprising government (military and civilian), contractor, and academic members will use the AAFRF platform to begin producing research quantities (10-15 gal/day) of experimental jet fuels derived from a wide range of alternative fuel feed stocks. Among these intended stocks are coal and various biological sources such as camelina, salicornia, palm, jatropha, soy, algae, waste animal fats, and similarly renewable substances.

As the AF Center of Excellence for the discovery, development, and integration of affordable and environmentally responsible aviation fuel alternatives, AFRL's Energy/Power/Thermal Division has already begun work towards certifying each type of aircraft in the AF fleet to fly on a 50/50 blend of conventional petroleum-based mailitary aviation fuel and synthetically generated fuel. With the addition of the AAFRF facility, researchers will now be able to design aviation fuels from plentiful, alternative, renewable sources as a means of eventually reducing—or even eliminating—dependence on foreign oil.

Axing the Competition

AFRL's Battle-Axe Ordnance program, which works to enhance the lethality of multimode ordnance packages, completed a successful test series for two integrated warheads. Supporting the lab's premiere micro munitions, the Battle-Axe warhead will increase the capacity of precision-guided submunitions (PGS) to defeat a broad range of ground targets, including soft fixed, soft mobile, and armored varieties.

Battle-Axe houses two primary kill mechanisms: a shaped charge and a fragmenting body, both of which utilize reactive materials. To collect detonation-related data, tests involved the warhead's static placement in the center of an arena containing rolled homogeneous armor (RHA) and mild steel targets, diesel targets, and RHA armor plates. Researchers also placed the warhead on a PGS seeker in order to test the seeker's effect on the warhead's shape-charge jet.

This advanced, highly lethal, and very versatile warhead will be small enough for large load-outs on a wide variety of air platforms (e.g., Low-Cost Miniature Cruise Missile, C-130 aircraft, and Predator and other unmanned air vehicles). Its proficiency in addressing a broad spectrum of targets will translate to reduced inventory requirements. Further, the warhead will achieve lethality regardless of target set—a capability driven by advances in reactive material densities and energy release. Compared to equivalently sized conventional warheads, Battle-Axe will match or increase lethality and do so in a smaller warhead package. Moreover, the technology's high probability of kill in defeating multiple, independent targets will significantly reduce the number of sorties required for a given mission.

Pictured is a detonation sequence captured during recent tests of the munitions technology.

An A-10C Thunderbold II from Eglin Air Force Base, Florida, flies along the coast during the first flight of an aircraft powered solely by a biomass-derived jet fuel blend.

AFRL Examines Renewable Fuel Sources

Illustrating AFRL's position at the cutting edge of alternative fuels exploration, an A-10C Thunderbolt II underwent recent flight demonstration powered on a blend of standard JP-8 fuel and hydrotreated renewable jet (HRJ) biofuel. The groundbreaking event marks one successful step in a more comprehensive Air Force (AF) undertaking to certify an entire family of biomass fuels. While the bio-based component used for the A-10–tested fuel blend is a camelina plant derivative, this particular substance is not the only option for producing HRJ fuel. On the contrary, wide varieties of plant oils (e.g., algae) and animal fats (e.g., chicken) are candidates in this capacity.

As the Department of Defense's (DoD) largest consumer of jet fuel, the AF uses 2.4 billion gallons per year, about the annual fuel equivalent of a midsized commercial airline. Accordingly, the service—intent on switching half of the continental US jet fuel requirement to alternative fuels by 2016—maintains an ongoing partnership with the Commercial Aviation Alternative Fuel Initiative to develop biofuels. As part of this collaborative endeavor, AFRL has examined a broad range of feedstock sources for their respective fuel production viability and ultimate cost-competitiveness with petroleum fuels. While engineers continue exploration along these lines, they have already completed a substantial amount of work towards realizing HRJ fuels and are turning their collective attention to the potential discoveries that lie ahead, such as fuels made from forest or agricultural waste and similarly eco-friendly and cost-effective capabilities.

Following another demonstration flight (this one involving an F-15) and static engine tests, the plan is to conduct full-blown certification test efforts with two Pathfinder programs: one with a C-17 representing the mobility fleet and the other with an F-22 Raptor representing the entire fighter fleet. Still under consideration is a third such program, which would likely employ the Global Hawk platform to evaluate the fuel in the extreme environment of "worst case" temperature and altitude. The intent is to be able to leverage a 50/50 blend of JP 8 and HRJ fuels without modifying existing system or fuel infrastructure. The certification program will apply to other platforms that burn JP-8 in wartime as well, such as remotely piloted vehicles, Humvees, and even power generators.

Notably, the breakthrough research of alternative fuels represents only a portion of the AF's plan to reduce oil dependency. AFRL is also working to reduce demand by developing advanced engines and other emergent technologies. Nonetheless, as the DoD, the aviation community, and the nation look to a shared future of independence from nonrenewable energy sources, the AF's historic strides in alternative fuels will yield positive economic and environmental outcomes of benefit to military and commercial interests alike.

For more information contact afrl.rz.techinfo@wpafb.af.mil • (937)255-3428

Patent Issued for Air Force Propulsion Technology

AFRL's Dr. Paul N. Barnes and coworker Dr. George Levin (UES, Inc.) recently earned a patent entitled "Machinery windings of yttrium barium copper oxide and related coated conductor." The recently issued patent is based on the pair's work in using a superconducting, tapelike electrical conductor in special winding configurations for magnets and electrical machines. The patented windings leverage the new yttrium barium copper oxide superconductor in a manner that can assist in avoiding situations where magnetic-flux-related losses are potentially excessive and preclude successful machine operation. The patent references the winding orientation and configuration of the conductor in an alternating current machine, such as a power generator, for realizing lower losses; it also discloses the methods for achieving the desired windings. It is important to note that this invention also enables windings intended for differing locations within a single machine of this type.

Pictured on the left is a model of a helical (layered) magnet/coil, and shown on the right is a model of a three-coil group for an armature winding.

Conceptual depiction of AFRL's RV 4 technology, which uses radar-based HRR to provide automated moving target identification

RV4 Moving Target Identification

AFRL conducted a successful flight demonstration of Radar Vision 4 (RV4), an important new capability for automated cueing and recognition of combat moving targets. Developed under the Air-to-Ground Radar Imaging (AGRI) Advanced Technology Demonstration (ATD), RV4 employs radar-based high-range resolution (HRR) technology to identify moving targets. Working with 13 different vehicle types in various convoy arrangements, researchers demonstrated real-time execution of RV4 using the Raytheon Multiprogram Testbed (RMT), which is actually a modified Boeing 727 aircraft.

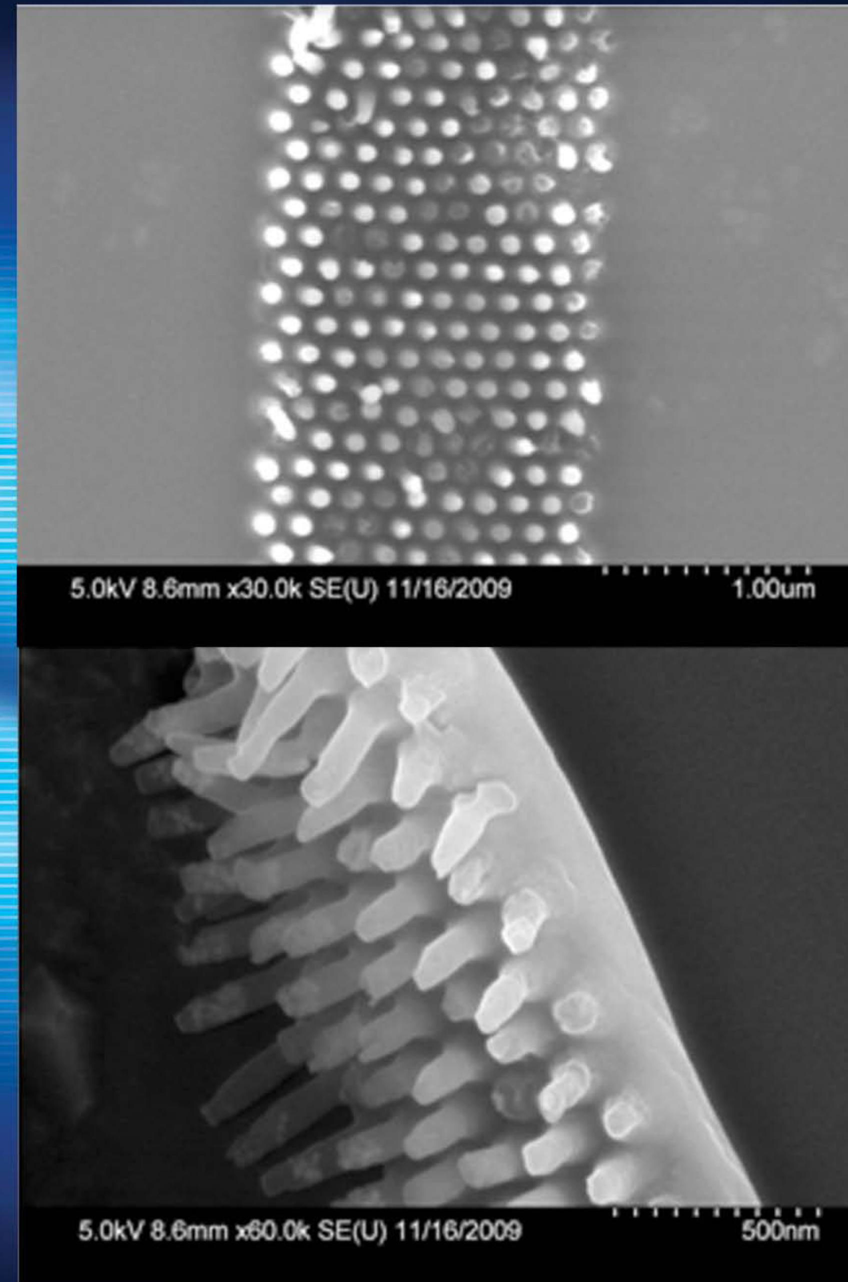
The chief purpose of this demonstration effort was to exercise the RV4 capability in real time, as well as to verify earlier test results from the AGRI ATD (completed in October 2008). Accordingly, the researchers collected and recorded all radar, HRR, and algorithm data in order to facilitate precise playback and analysis of each RMT pass in the laboratory. Postprocessing of this assimilated data will play an essential role in verifying key performance parameters for the newly demonstrated capability.

In addition to fulfilling the primary goal of verifying real-time performance and previously acquired test data, this RV4 technology demonstration also generated promising results with respect to the use of surrogate radar data for algorithm training, an application that could potentially reduce associated database costs.

Nanolithography Nets Biopolymer EO Device Improvements

Researchers from AFRL and the University of Arizona collaborated to demonstrate the first-ever fabrication of DNA biopolymer nanostructures via nanoimprint lithography, a technology of merit for low-cost, portable (in-field) production of chemical and optical sensors, high-speed communications, and electrical device components with enhanced performance for warfighters.

Compared to their inorganic counterparts, biopolymer-based electro-optic (EO) devices are less expensive and offer potentially better performance as a result of their lower losses and operating powers in communications and sensing devices. Based on the successful outcome of this technology demonstration, AFRL has invested in a state-of-the-art nanoimprint lithography system that will enable EO device fabrication for both biomaterials and inorganic materials.



Pictured are atomic-force microscope images of a nanoimprinted DNA biopolymer; the diameter of each pillar is 70 nm, and the height is >150 nm.

A Morpho butterfly wing exposed to a chemical vapor (pictured left), as compared to the insect's normal wing (pictured right)

Butterfly Biology Inspires New Sensing Capability

A collaboration of AFRL, General Electric (GE), and academic researchers are leveraging the chemical sensing properties of butterflies to develop nanostructured photonic sensors that, if implemented, would not only enable faster and more selective detection of dangerous chemical warfare agents and explosives, but also expedite the development of responsive materials for countering the harmful entities. The bio-inspired sensing technology will thus have a variety of important military and commercial uses in this vein.

Since their discovery 3 years ago that the nanostructures present on butterfly wing scales exhibit acute chemical sensing properties, GE scientists have been working to develop a new sensing platform that replicates these unique characteristics. Throughout their endeavor, the researchers have observed—and been motivated by—countless examples of naturally occurring optical structures with properties arising from an intricate morphology. For instance, the brilliant hues seen in butterfly wings, beetle carapaces, and peacock feathers are due largely to structural complexity, not simply color. The Defense Advanced Research Projects Agency (DARPA) is attempting to harness the best of nature's own photonic structures while exploiting advances in materials technology in order to create controllable photonic devices at visible and near-infrared wavelengths. As part of DARPA's recent funding of an effort to examine the technology's feasible use in improving homeland security, AFRL and GE joined forces with scientists from the State University of New York at Albany and the University of Exeter, United Kingdom, to conduct the necessary research.

The team's results indicate that the biologically based sensing platform could dramatically increase sensitivity, speed, and accuracy in the detection of hazardous chemical threats. The devices can be very small, and their diminutive aspect—coupled with their inherently low production costs—will permit their ready manufacture and deployment wherever needed. These size and production advantages, combined with the unique sensing capability itself, could extend the technology's use to a host of commercial applications, including emissions monitoring, food and beverage safety monitoring, water purification testing, breath analysis for disease detection, and wound healing assessment.

New Antennas Conform to Air Vehicles, Not Status Quo

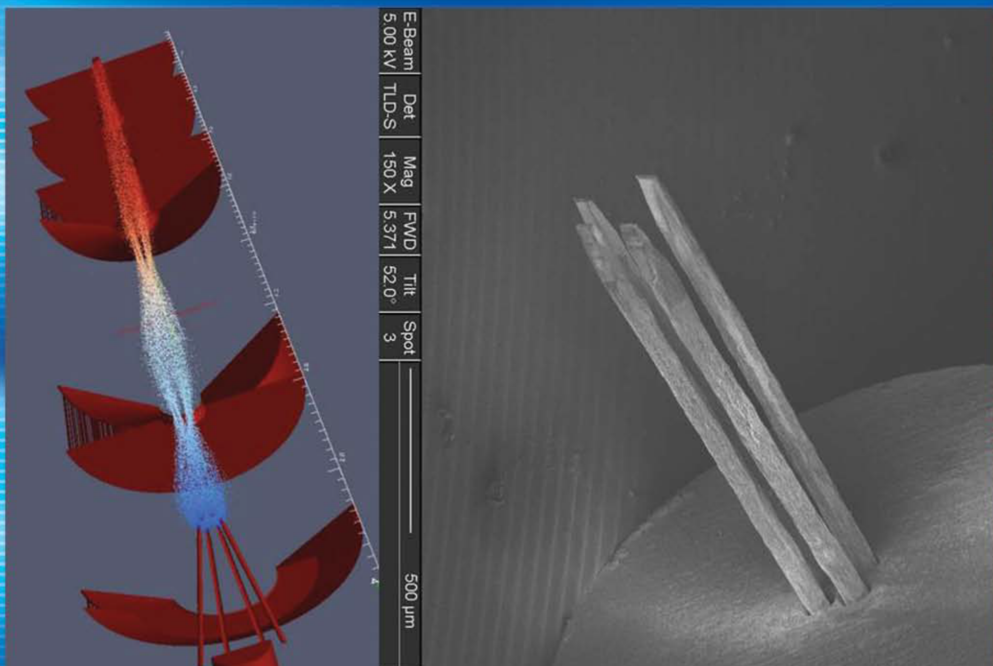
AFRL is developing conformal load-bearing antenna structures (CLAS) as an affordable improvement to the current generation of alternative antenna systems. With the ultimate goal of replacing costly, bulky antennas that disrupt airflow with affordable, low-profile antennas that are conformal and can be structurally integrated with air vehicle platforms, this Manufacturing Technology (ManTech)-based, Defense-Wide Manufacturing Science and Technology–driven program is providing key insights regarding present-state antenna manufacturing processes and emergent CLAS fabrication methods alike.

Conventional antennas are very expensive and difficult to manufacture; further, their subsequent mounting or housing aboard vehicle platforms requires extensive structural modifications. The use of CLAS technology in surface-mount antenna elements is therefore an attractive alternative to existing systems. Researchers expect that the integration of CLAS into air vehicles will increase aerodynamic efficiency, decrease weight and drag, improve platform endurance and speed, and minimize installation impacts. The technology will also enable radar capability on smaller platforms and enhance situational awareness for Air Force systems operators.

During the CLAS project, ManTech and Boeing researchers collaborated to conduct a Manufacturing Readiness Assessment (MRA) for determining the current state of CLAS manufacturing maturity in order to identify areas for improvement. The MRA prompted key advances in the area of CLAS modeling, materials, and manufacturing readiness, as demonstrated by the resultant prototypes. A VHF [very-high frequency] blade antenna was chosen as the conventional antenna to be replaced by a CLAS design. The initial prototype developed using the down-selected materials and simulated geometry achieved the required bandwidth. With a revision to the antenna shape, the second prototype complied with the required center frequency. The final (third) prototype, which underwent manufacturing in a production environment, was embedded into the conformal surface of a 737 wing-to-body fairing and complied with the radio frequency requirements set for the project.

Pictured is the third CLAS prototype, which has a complex, curved configuration.

Materials Innovation Amplifies Terahertz Power and Performance



SWNT fiber made to design specifications for a traveling wave tube amplifier

AFRL materials experts' discovery that single-walled [carbon] nanotubes (SWNT) boost terahertz imaging capabilities resolves a fundamental limitation in the lab's Hazardous Material Identification System. That directed energy system has heretofore generated its terahertz beam via traveling wave tube amplifier; however, the limited current density of the carbon-fiber-based cathodes used for device emissions has restricted the system's power and, thus, its range and resolution. In pursuing the desired enhancements, the scientists conceived of using SWNT fiber cathodes in the system's electron gun. The outcome of this exploratory effort, a collaborative venture with Rice University, is a material solution not only more durable than carbon fiber counterparts, but more powerful (10x greater current) and less power-hungry (4x lower turn-on voltage). Though originally devised for military purposes, this technology could also benefit terahertz systems used for security surveillance, medical diagnostics, nondestructive evaluation, production quality control, and similarly diverse applications.

Imaging via "terahertz" entails the use of electromagnetic waves sent at frequencies in the terahertz range. Waves in this range can pass through clothing, paper, cardboard, wood, masonry, plastic, and ceramics, making terahertz imaging a technology of choice for security surveillance and other noninvasive (but detection-oriented) applications. Further, the nonionizing properties of waves in this range pose no risk to human tissue, which heightens the technology's appeal for medical use. SWNTs, meanwhile, are unparalleled in their combination of strength, stiffness, thermal and electrical conductivity, and field emission. Consequently, the AFRL/academic team set about investigating the properties—and potential applications—of SWNTs spun as a polymer into 100 µm diameter continuous fibers via a process similar to that used for Kevlar™ production.

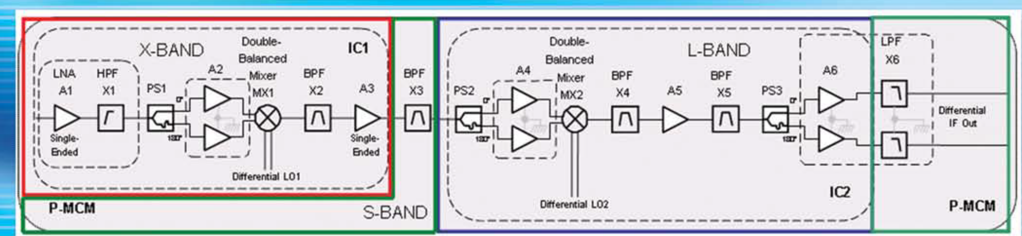
Long-term testing indicates that SWNT fibers demonstrate substantially improved emission current and exhibit minimal damage compared to carbon fibers, which produce limited current and suffer catastrophic failure due to Joule heating. The team's groundbreaking work has established an Air Force–unique cathode material, prompted a patent application addressing SWNT fibers as a cathode material, and shifted the research focus on carbon fiber cathodes towards implementing SWNT-based technology instead.

Self-Healing Circuits Boost Performance, Cut Costs

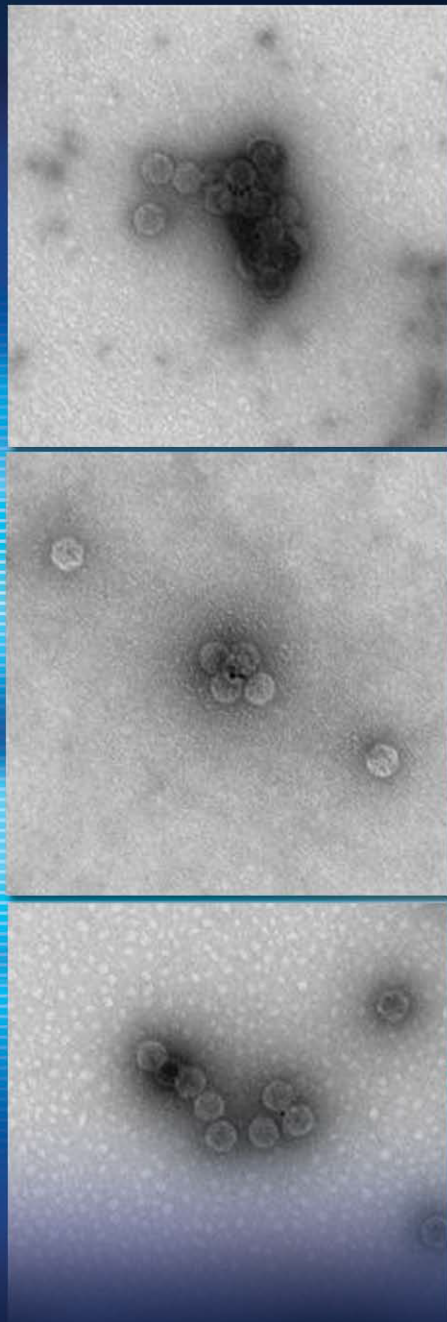
In supporting the Defense Advanced Research Projects Agency's (DARPA) pursuit of affordable high-performance electronics, AFRL sensors scientists are addressing the tendency of high-frequency integrated circuits to become increasingly smaller and, further, more costly due to mounting difficulties in achieving totally defect-free parts. The diminishing yields of quality circuits, which are critical components of every major military weapons system, are caused by environmental and process-related effects—or more specifically, defects—that combine to limit circuit performance. To combat this issue, the research team recently demonstrated on-chip sensors and actuators designed to automatically adjust a given circuit's performance to negate defect-induced degradation. Essentially, these self-healing, mixed-signal integrated circuits, or HEALIC, adjust to existing conditions in order to maintain the desired level of functionality.

As part of aiding the DARPA effort to realize this self-healing capability, sensors scientists managed the development of a wideband, 6-18 GHz receiver-on-a-chip with baseband outputs. Concept chip fabrication occurred via an advanced, 65 nm CMOS (complementary metal oxide semiconductor) technology, with the subsequent demonstration activity presenting the integrated designs containing this self-healing circuitry. The newly-concept-demonstrated chips will next undergo test with and without self-healing algorithms in order to demonstrate their capacity to maintain performance parameters without significant increases to the size or power consumption of the integrated circuit in which they reside.

The Phase I goal is to achieve greater than 75% performance yield and less than 10% power consumption overhead, whereas Phase II will demonstrate a complete HEALIC with greater than 95% performance yield and less than 5% power consumption overhead. Ultimately, the self-healing technology will have a major impact on the defense community's access to economical military electronic systems offering extended lifetimes and high performance even in extreme mission conditions.



As part of supporting a DARPA effort to create self-healing integrated circuitry, AFRL sensors scientists oversaw development of a wideband, 6-18 GHz receiver-on-a-chip with baseband outputs, the architecture of which is illustrated.



Transmission electron microscope pictures reflect gold nanoparticles attached to viruses..

Gold Nanoparticles Increase Viral "Brainpower"

As a first step in exploring viral (peptide) bonding mechanisms that could eventually form the building blocks of highly complex computational systems and other transition-metals-based technologies of tomorrow, researchers from AFRL and the University of Mexico discovered a way to synthesize specific peptide sequences that bind metal nanoparticles to a virus. The most recent transition element to have undergone successful bonding (with the Q beta virus) is gold.

One of the smallest symmetrical structures in nature is that of a virus, which self-constructs via peptide sequences. A peptide is a short polymer created from the linking, in a defined order, of amino acids forming a bond. A peptide sequence is the order in which amino acid residues, connected by peptide bonds, lie in the chain of peptides and proteins. The idea of nanotechnology is to engineer a biological device that would naturally self-assemble into fundamental logic gate structures, specifically using the spherical MS2 and Q beta viruses.

Chemically modified to the peptide sequences in the viruses are nanometer-sized elements, in this case gold. The concept is that these viral building blocks would then be able to form a highly complex computational system, comparative in power to having several million human brains on a single chip, with the storage capacity equivalent to 50 copies of the entire Library of Congress. Subsequent efforts to bond peptides to transition metal materials could potentially create semiconductors, as well as composite insulators for basic transister device components.

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Interturbine Burners Ignite Quest for Fuel-Efficient Engines

The successful demonstration of Small Business Innovation Research (SBIR)–enabled interturbine burners (ITB) in an FJ44-3 engine furthers the ITB technology's viability towards improved operational versatility of gas turbines for a variety of military systems, including manned and unmanned aircraft and missiles. Specifically, ITBs increase fuel efficiency via adjustments to the thermodynamic cycle and optimization of the main combustor's capacity for partial-power operation. Such efficiency improvements can translate to longer flight, greater payload and/or fuel capacity, and reduced aircraft operation costs.

The Phase II SBIR effort—completed by a team of Creare, Inc.; Williams International (WI); and AFRL propulsion engineers—marks the first-ever demonstration of an ITB with a WI engine. The burner achieved successful light off at 32,000 rpm; 34,000 rpm; and 36,000 rpm N2 [core compressor spool rotational] speeds, back-to-back trials that generated emissions results and other significant data. The demonstration revealed that ignition events occurred below the target fuel flows and also confirmed that the ITB stays lit and stable with the igniter off at all conditions considered.

Shown here in demonstration mode, ITBs are based on the trapped vortex combustor technology developed over the years by government and industry teams.

AFRL worked with Air Force Space Command's Space Development Test Wing and Vulcan Wireless to create the Genesis Black Box (pictured), which improves access to spacecraft functional data.

The Genesis of Better Satellite Telemetry

The success of AFRL's Genesis Black Box program translates to a breakthrough capability for transmitting critical satellite data—whether emergency or nonemergency—from almost anywhere in space to the ground. A recent launch activity confirmed the viability of using a local sensor suite for autonomous data capture and leveraging the Tracking and Data Relay Satellite System (TDRSS) infrastructure for data download. With the launch rocket serving as the "satellite" for demonstration purposes, the Genesis Black Box tested the capacity of the TDRSS to track transmissions from a dynamic, spinning body. The positive outcome of this experiment paves the way to the creation of tiny transponders that will one day be embedded in every spacecraft, including rockets.

The Genesis Black Box transponder is to spacecraft what the black box radio device is to airplanes. As such, it captures not only satellite functions, including power levels and payload status, but malfunctions in such areas as well. The point, as with conventional airplane devices, is to be able to retrieve an operational snapshot in the event that an incident occurs. Unfortunately, the fact that the black box designs presently used aboard spacecraft must be located, collected, and analyzed after an incident means that knowledge remains inaccessible until—or worse, unless—the device is able to reenter the atmosphere and returned to the earth. Along the lines of reentry difficulties, the current designs must be very large and heavy in order to survive the event.

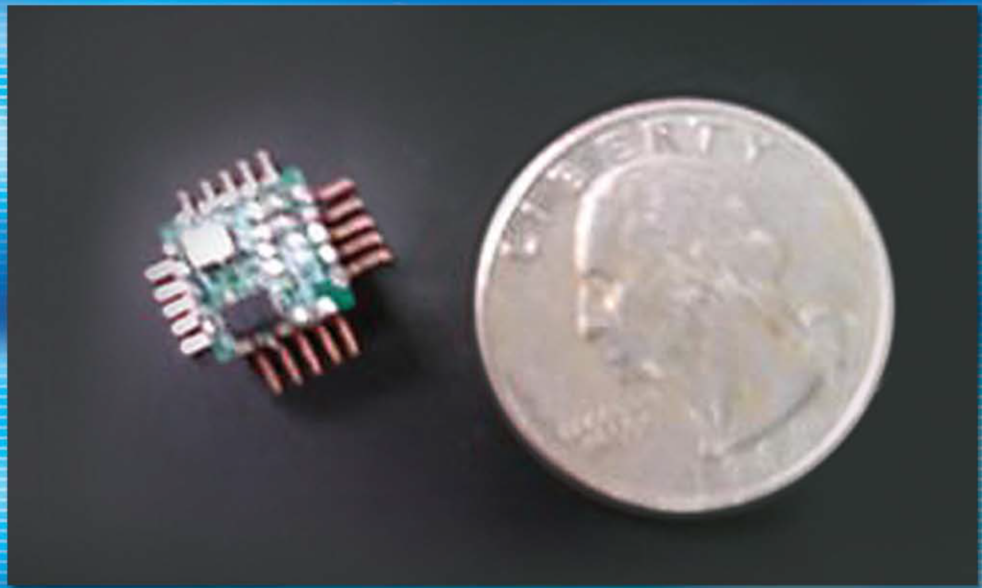
The Genesis Black Box provides a solution to these shortcomings. Instead of merely storing information, it transmits forensic data from spacecraft to ground immediately after an incident occurs, eliminating the requirement—and the associated concern—of surviving reentry and with it, the need for excessive size and weight. On the contrary, the Genesis Black Box is much smaller and uses negligible power compared to its predecessors. Selected by the lab as one of just eight programs (of the original 34 responding to a call for innovative research issued at the end of Fiscal Year 2009), this effort involved collaboration across government, academia, and industry.

Mini-PnP: Space Responsiveness à la Carte

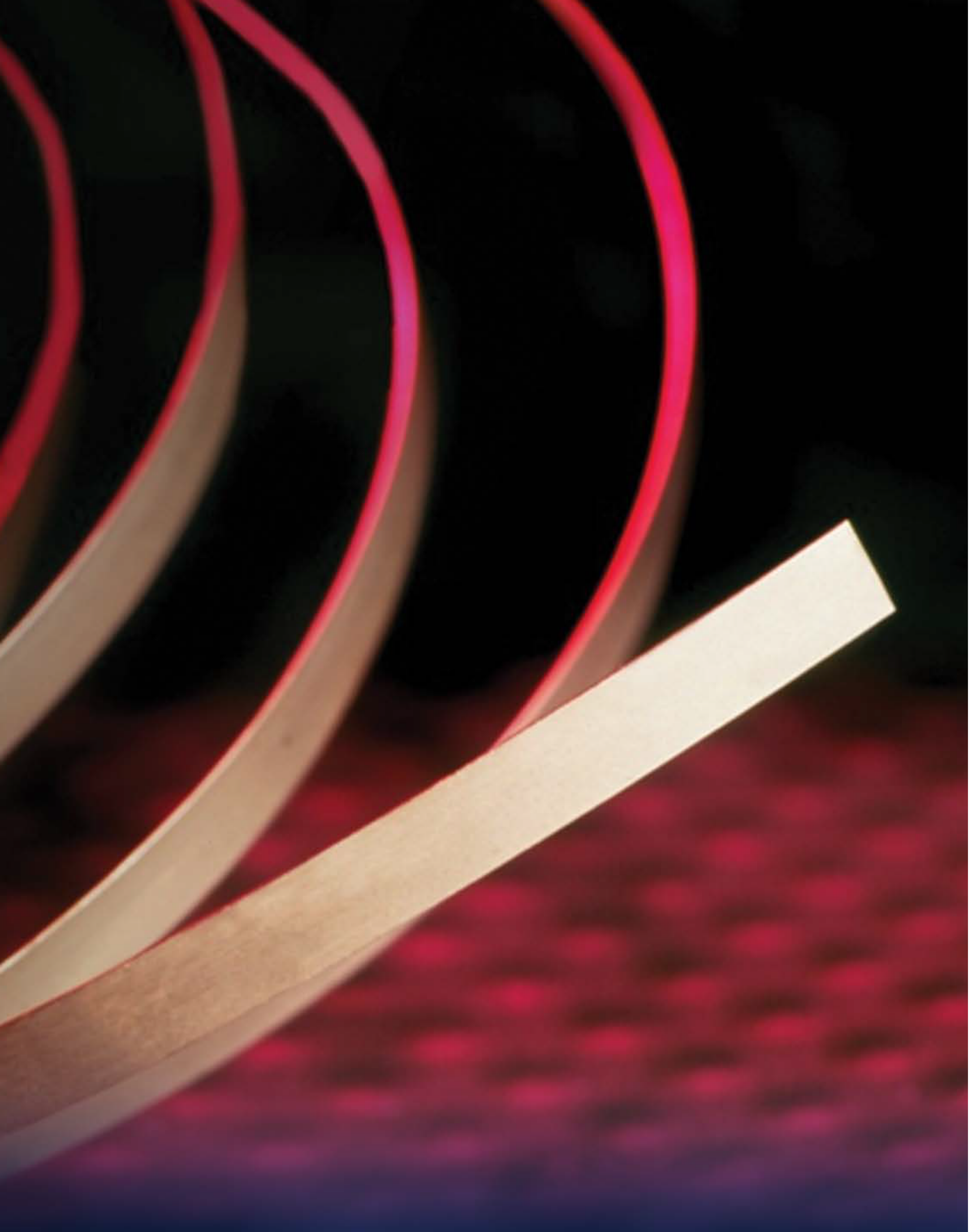
In the ongoing pursuit of operationally responsive space (ORS) technologies, AFRL scientists created the first miniature plug-and-play (PnP) Appliqué Sensor Interface Module (ASIM). The mini module, Space Plug-and-Play Avionics (SPA)-1, is an ultracompact, ultra-low-power protocol that supports the many different PnP component types that do not require the existing, high-bandwidth capabilities of SPA-U (USB) or SPA-S (spacewire).

As a modular approach to creating complex systems—ORS satellite systems, in this case—PnP encompasses both hardware and software components. It also includes the standards in place for the use and interaction of these elements. In conjunction with government, industry, and academic partners, AFRL created the SPA framework as its self-imposed regulatory (i.e., standards) system for rapidly developing and implementing spacecraft via PnP. In addition to facilitating quick-turnaround PnP satellite (PnPSat) systems, SPA also provides considerable cost advantages over traditionally constructed PnPSats, fully supporting à la carte assembly of intricate sensor and actuator configurations and, further, accommodating both network expansions and modifications. While SPA-U is based on the established USB (version 1.1) interface standard and supports 12 Mbps data transport, SPA-S is a European Space Agency standard that accommodates even higher data transport rates (to date up to 625 Mbps) via spacewire link.

As a forerunner to its breakthrough mini module, AFRL created the original ASIM as another facet of a standardized approach to ORS. Dubbed the "universal translator," it provides sensor and control communication over a SPA channel using either lower-speed or higher-speed protocol. The technology is applicable both to the design of new equipment and to the adaptation of existing equipment. Now, pending arrival of the miniature version's in-house-designed development board, the 8 x 8 mm form factor ASIM will undergo testing. This work effort is part of the international collaboration between AFRL and FMV (Swedish Defence Materiel Administration, or Försvarets materielverk).



Mini-PnP ASIM



VIM-VAR steel

DoD Steels for Growth in Key Production Capacity

As part of a Defense Production Act Title III effort centered on the military's crucial need for specialty steels, AFRL and Latrobe Specialty Steel constructed the world's largest vacuum induction melting (VIM) furnace. Having a readily accessible, high-volume capacity for VIM (coupled with the secondary process of vacuum arc remelting, or VAR) is essential to producing high-performance, high-quality engine bearings, helicopter motor shafts, transmission gears, engine mounts, and similarly vital components for military use.

Specialty steels are critically important to virtually every US defense platform. In order to reset, recover, and rehabilitate military material resources from the effects of ongoing combat operations abroad, the Department of Defense (DoD) must have VIM-VAR, low-alloy, iron-based steels, specifically. It is only these remelted alloys that meet the tensile strength, wear resistance, and fatigue requirements critical to defense applications. VIM-VAR steel is a highly refined material processed through multiple melts, under vacuum in order to reduce excess gases and other impurities. During VIM, metal melt occurs under vacuum conditions achieved via electromagnetic induction. It works by creating electrical eddy currents in the metal, which heats the "charge" to melt the material. The process refines high-purity alloys. VAR refers to the secondary melt process by which metal ingots with elevated chemical and mechanical homogeneity are produced for use in demanding aerospace applications.

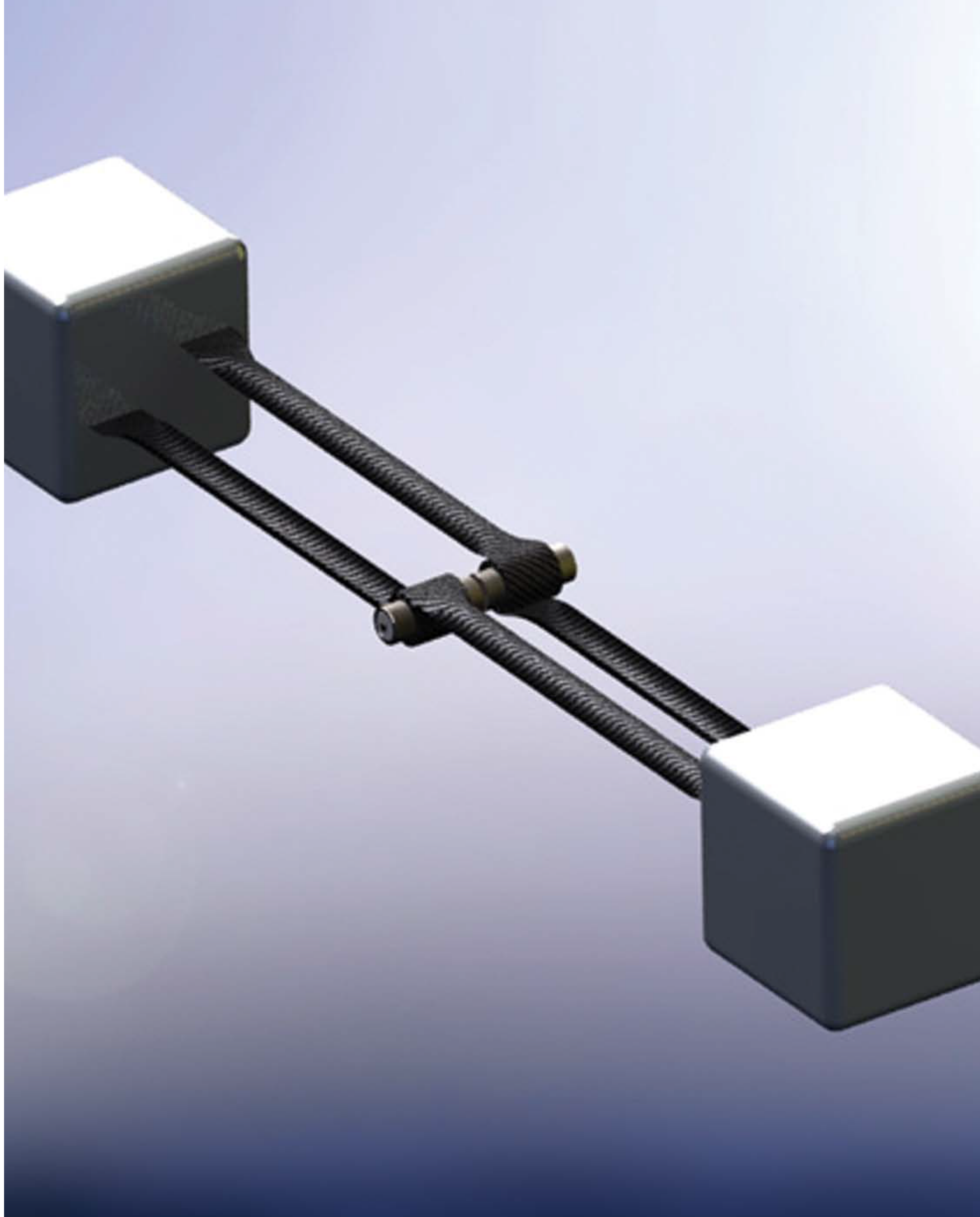
Since 2004, the lead times for acquiring VIM-VAR material have increased from 12 to upwards of 72 weeks, the unfortunate result of industry's fiscal reluctance to expand VIM furnace capacity to meet commercial and DoD demand alike. Consequent to these steadily lengthening lead times are higher procurement costs for defense weapon systems, due primarily to inventory carrying costs and management fees, and associated supply chain disruptions for DoD components. The lab/Latrobe work towards an expanded VIM-VAR production capacity reduces order lead times from 72 to 20 weeks and, further, ensures a reliable domestic manufacturing source for military purposes. As a result of this project, Latrobe received the American Metal Market's Best Operational Improvements Award, presented in June 2010.

In-Progress Invention a Booming Success

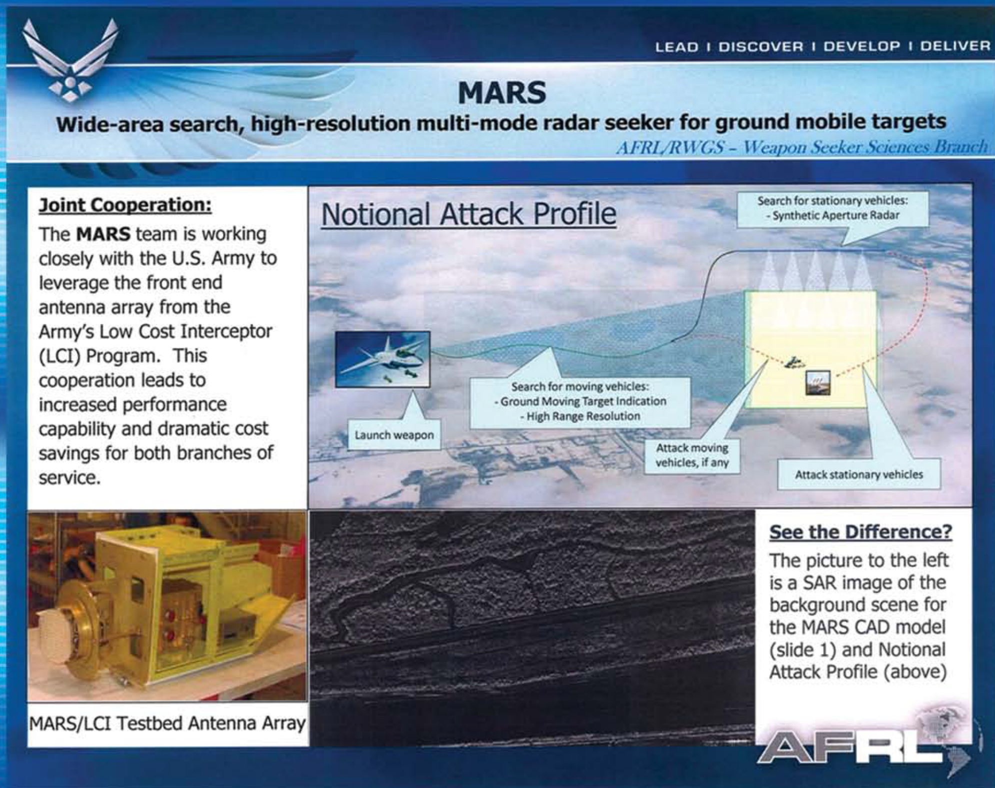
With the filing of an invention disclosure, a new deployable boom based on composite tape-springs may be on its way to becoming patented technology. Under codevelopment by AFRL and LoadPath, LLC, the boom uses stored elastic strain energy to self-deploy, requiring external power only to activate launch release devices. Its use of coiled tape-spring pairs prompts the linear separation of two spacecraft components as the tape-springs unroll, with the asymmetrical side-by-side placement of two such coiled pairs creating a stable structure with controlled deployment.

Regarding structural stability, the tape-springs actually exhibit bistability, a unique feature similar to that observable in the toy commonly known as a "slap bracelet." If a structure is bistable, it is stable in two different configurations and can be repeatedly and elastically deformed from one shape to the other. In this case, the two shapes are the fully rolled tape-spring and the fully unrolled tape-spring. Because the unrolled shape stores less strain energy, deployment progresses freely once initiated—a property that, in turn, enables the invention to eliminate canisters, motors, and other constraint mechanisms typical of existing tape-spring booms.

The first version of the boom technology will come in the form of a CubeSat gravity-gradient stabilization boom that expands from its 3 cm packaged length to a 3 m total length. This passive attitude-control approach has authority over two spacecraft rotation axes and ensures the satellite remains nadir pointing throughout its life. Spacecraft communications, power generation, and sensor functions all stand to benefit greatly from the advent of such an improved type of attitude-control system.



As shown, the novel boom uses two coiled tape-spring pairs to achieve linear separation of two spacecraft components as the tape-springs unroll.



MARS program schematic

On a Mission to "MARS"

In completing a series of captive flight tests for the Multimode Advanced Radar Seeker (MARS) program, researchers marked a major milestone towards demonstrating the viable use of small, low-cost radar technology for autonomously engaging ground-based mobile targets in the face of substantial locational uncertainty and/or adverse weather conditions. MARS is a small-aperture, multimode radar that leverages ground moving-target indication, high-range resolution, and synthetic aperture radar modes to rapidly acquire, classify, and track mobile targets. Accordingly, the MARS program strives to provide a foundation for the established use of multimode radar functions in small, affordable weapons guidance applications. The technology's flexibility also makes it relevant for use in surface-to-air weapons, small unmanned air vehicles used for surveillance, and unmanned combat air vehicles.

The recently concluded test phase, completed by AFRL and Northrop Grumman, provided an opportunity to demonstrate real-time performance both for each mode separately and for all modes in concert. The team conducted a total of 15 captive flight tests, culminating with 5 system demonstrations flown over test ranges at Eglin Air Force Base, Florida. The demonstration flights sought to further prove the capacity of MARS to execute a mission scenario involving the engagement of military mobile targets, whether moving or fixed. The AFRL/industry team is currently conducting postflight data reduction and analysis in order to quantify system performance.

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Science "CAREs" About Edge-of-Space Cloud Behavior

In the interest of investigating the phenomena of noctilucent—or night-shining—clouds, AFRL worked with other science community participants to assist the Naval Research Laboratory and Department of Defense Space Test Program in launching the Charged-Aerosol Release Experiment (CARE) rocket. The spacecraft's successful launch from the National Aeronautics and Space Administration (NASA) Wallops Flight Facility, Virginia, took place aboard a NASA four-stage Black Brant XII suborbital sounding rocket. For its part, AFRL collected measurements of the release using optical equipment deployed to Cape May, New Jersey, along with Global Positioning System and ultra-high-frequency receivers located at Martha's Vineyard and aboard a downrange boat.

Although difficult to spot with the naked eye, naturally occurring noctilucent clouds are best visible just after sunset, when sunlight from below the horizon illuminates them. Also known as polar mesospheric clouds, noctilucents consist of ice crystals and are the highest clouds in the earth's atmosphere, tending to hover around 50 to 55 mi above the planet's surface. Released a bit higher than this (at about 173 mi altitude), the CARE rocket's exhaust particles will trigger an artificial cloud formation that simulates natural noctilucents and thus enables associated data collection. This experiment will not only help scientists gain insight into the formation, evolution, and properties of noctilucent clouds, but also assist their development and validation of simulation models for predicting the upper-atmospheric distribution of dust particles from rocket motors.

CARE will help scientists acquire information about noctilucent cloud phenomena and the potential implications to space operations.

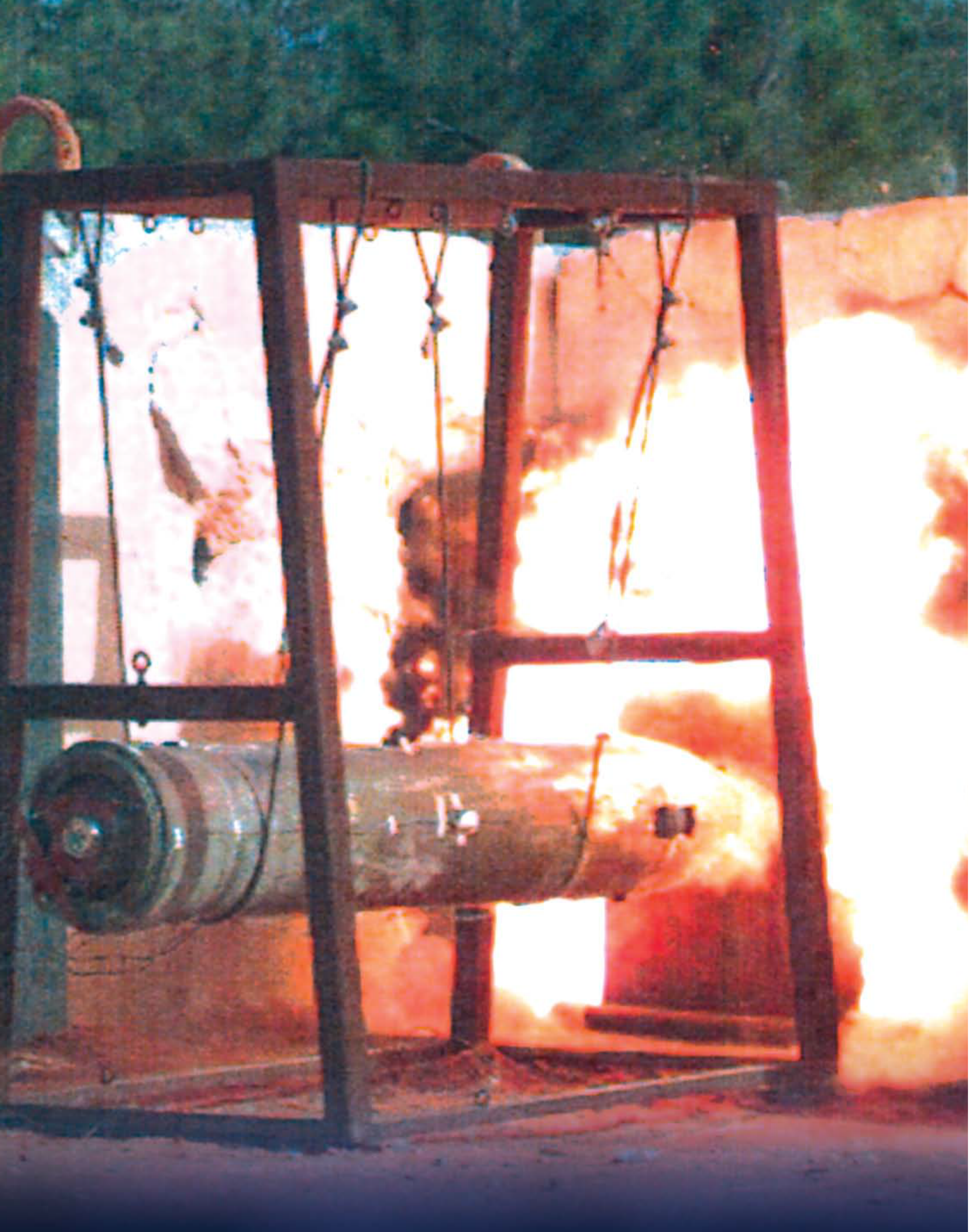


Image captured during pyroshock testing of an instrumented penetrator

Pyroshock Testing of Hard-Target Fuzes

In an effort to improve the survivability of intelligent fuzes in hard-target penetrators, AFRL munitions experts are conducting a series of pyroshock tests that will reproduce—and enable characterization of—the response of fuzing systems to shocklike mechanical input forces. A principal advantage of pyroshock testing is that data can be collected in a static frame of reference at higher rates and with greater fidelity and more sensors than traditional ballistic penetration testing permits. Test instrumentation included a penetrator equipped with strain gauges and acccelerometers housed in a canister (representing the fuze). A transfer bar—impulsively loaded via explosives—transmitted resultant shock loads to the instrumented penetrator. Novel data reduction techniques facilitated analysis of the fuze system's response data, with early results revealing a strong nonlinear response and thus deepening the team's understanding of penetrator dynamics. These results will ultimately assist efforts to improve next-generation intelligent fuzes and penetrators for defeating hard, deeply buried targets.

The pyroshock tests are part of an in-house program geared towards measuring the forces imposed on fuzes during hard-target penetration. Although no single lab test can reproduce the full range and complexity of shock loading phenomena observed during penetration, individually designed tests can adequately replicate various aspects of the penetration environment. Pyroshock tests are generally characterized by short-rise-time, short-duration, high-acceleration shocks imparted to the structure. By leveraging pyroshock techniques on penetrators, researchers can produce a realistic test wherein these sharp impulses are added to the global, dynamic response of the penetrator and subsequently measured by external and internal instrumentation.

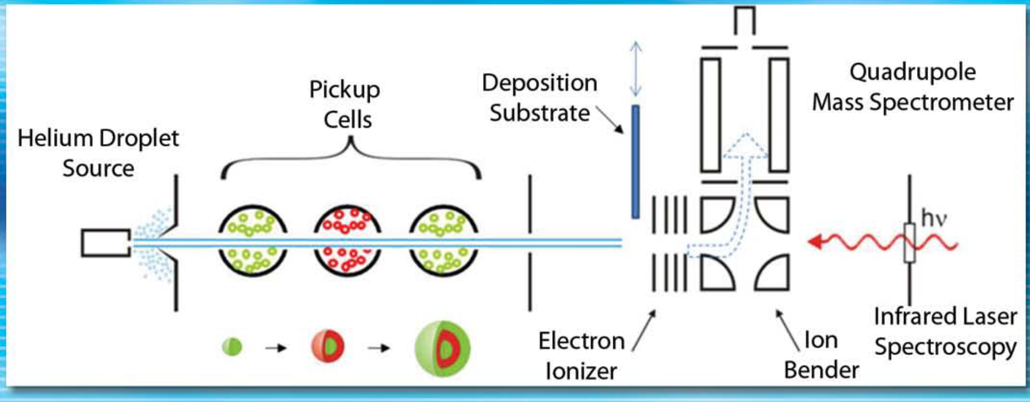
Future development of this test capability will include improved data acquisition and more diverse sensors (including new digital image correlation techniques). Also very applicable to the design and testing of new weapons concepts, this technology is undergoing transition for use in ongoing Air Force research programs.

For more information contact afrlmark@eglin.af.mil • (850)882-3009

Energetic Nanoclusters Explode Onto Munitions Scene

With conventional explosive formulations having reached a plateau of sorts, scientists are examining new energetic systems that, based on their higher energy densities, could yield advanced munitions capabilities. The major hurdle has been the inability of these emergent systems to release energy at a rate high enough to cause detonation. One way to increase the energy release rate is to make individual particles very small—on the order of a nanometer. Accordingly, AFRL's newly installed Superfluid Helium Droplet Assembler (SHeDA) does just that, effectively synthesizing nanoclusters of energetic materials. The novel apparatus—the first machine of its kind in the Department of Defense—can produce composite nanoclusters sized between 0.5 and 5 nm. SHeDA is therefore a boon to the timely and inexpensive energetic systems research driving the munitions breakthroughs of tomorrow.

SHeDA uses helium (He) droplets as "microbeakers" for nanocluster synthesis, first pressurizing and cooling the He before then expanding it through a 5° μm diameter aperture into a vacuum. During expansion, the He cools to 0.4° K and forms droplets consisting of He atoms between 10^3 and 10^7 in size. Scientists use He because no other known element is a liquid at these low temperatures. Next, the He droplets pass into a pickup cell containing a vapor of the desired coating material. When a cold He droplet collides with this vapor, the desired material freezes immediately as a cluster inside that droplet, which then continues its path through the machine. In the present setup—housed at Eglin Air Force Base, Florida—the He-droplet-enclosed nanocluster can travel sequentially through two more pickup cells, thereby producing clusters comprising up to three layers. This capacity for coating nanoclusters with inert materials holds great potential in the production of insensitive munitions.



SHeDA schematic showing (left to right) He droplet source, pickup cells wherein nanocluster synthesis (layering) occurs, and diagnostic instrumentation

TECH TRANSITION/TRANSFER

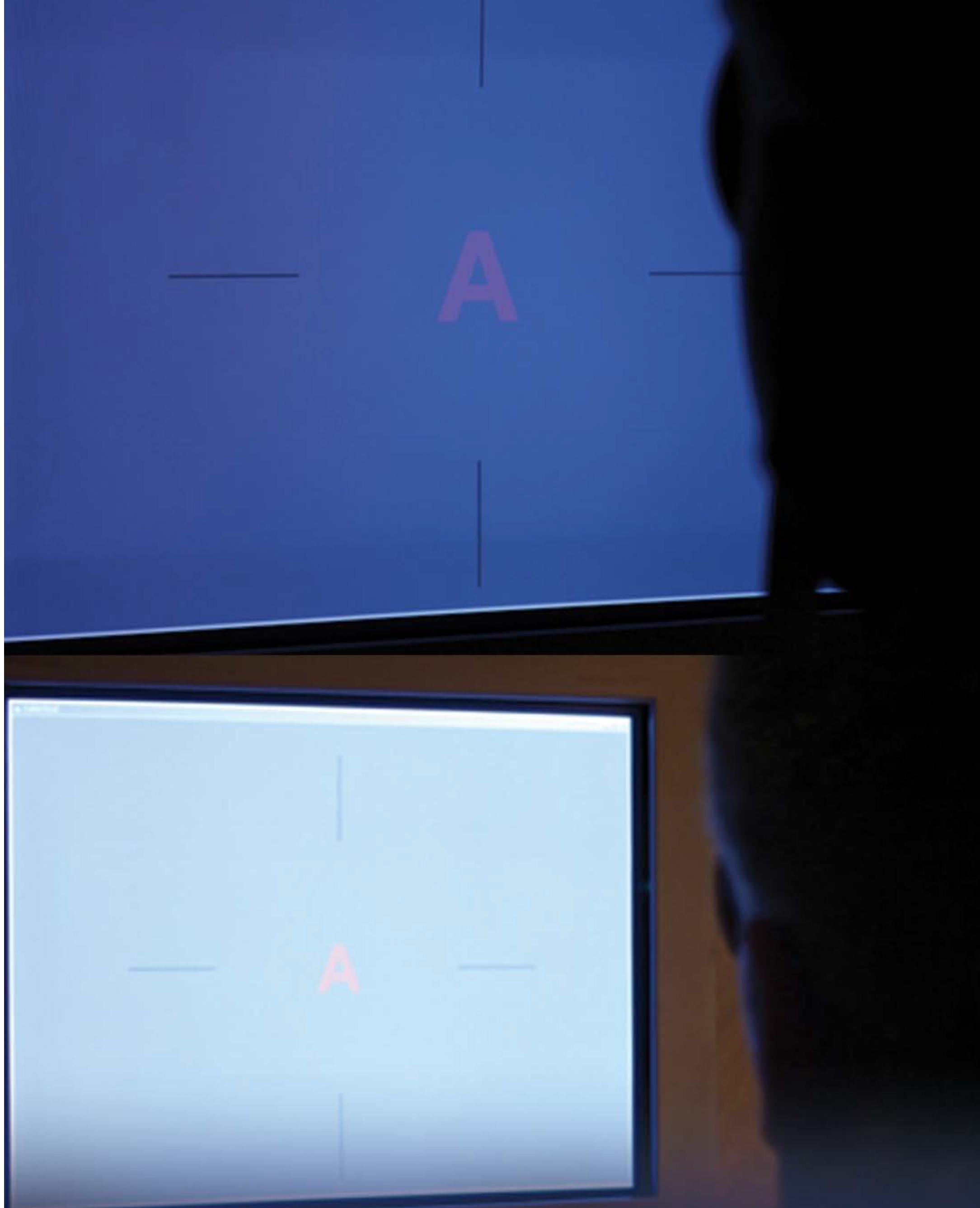
A New (Color) Vision for Pilot Safety and Performance

AFRL is working with Innova Systems, Inc., to implement a new color vision test that addresses issues with current test methods and thus improves warfighter—particularly pilot—safety and effectiveness. The Cone Contrast Test (CCT) indicates deficiency type (red, green, or blue) and severity (mild to severe); it also quantifies the realm of normal color vision. Further, the CCT distinguishes hereditary color vision loss from that caused by disease, trauma, medications, and environmental conditions. The new capability also supports Air Force (AF) Operational-Based Vision Assessment, a program highlighting the need to recognize deficiency levels in order to weigh the risks to mission success.

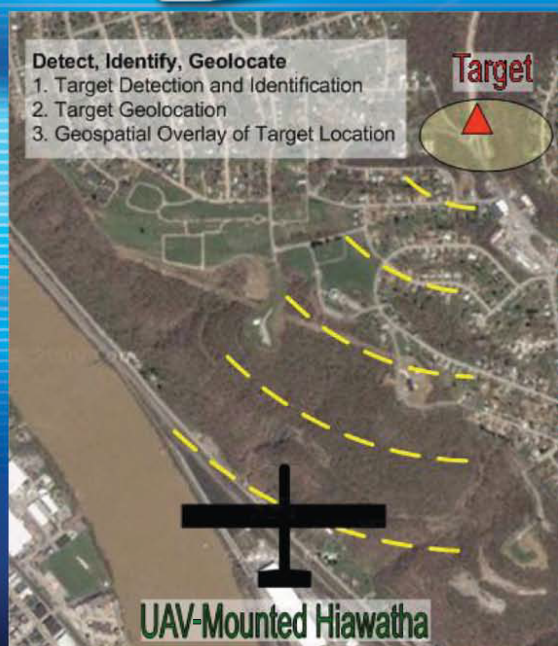
Whether genetic or acquired, color vision deficiency (i.e., color blindness) makes it challenging (or impossible) to hold certain jobs in military and civilian sectors alike. For pilots, seeing colors accurately is instrumental to success and even survival. Consequently, pilot candidates must be excluded if they have any degree of color vision deficiency. Unfortunately, current tests are typically pass/fail, an approach notorious for incorrectly labeling as "normal" [that] color vision which is, in fact, deficient. In the advanced, color-rich, modern military aircraft cockpit, such undetected deficiency—however slight—is problematic.

Seeing colors accurately relies on a complex mechanism involving the retina, a neuromembrane lining the inside-back portion of the human eye. The retina contains two types of light-sensitive cells, rods and cones, which convert light energy into signals carried (via optic nerve) to the brain. Only the cones—characterized as red, green, and blue types—are sensitive to color. The CCT is superior to conventional tests in that it presents a random sequence of colored letters, each visible to just one cone type at a time, in order to provide a cone-specific numeric score. This score aids decisions about occupational selection; it also facilitates the detection and monitoring of disease.

The technology's transition as a field-deployable unit to 100 AF bases nationwide will reduce travel to test-specific bases, netting savings estimated at $100,000 per year. Savings from improved safety and performance—though more difficult to predict—could easily reach tens of millions of dollars for every military aircraft accident avoided. Since the prototype CCT's trial runs, the AF has seen a dramatically increased percentage of candidates accurately identified as color-vision deficient. Accordingly, AF senior leadership has directed servicewide fielding within the year, and other Department of Defense, international, and civilian agencies are moving to employ the system as well.



Pictured (top) is the blue-cone-type and pictured is the red-cone-type (bottom) segment of AFRL's CCT, a software-based clinical color vision test that not only indicates the type (red, green, or blue) and severity of color vision deficiency, but also quantifies normal color vision.



RADICAL system (pictured top). Enhancements to RADICAL's geolocation functionality add capabilities such as geospatially mapped overlays of target electronics (pictured bottom).

"RADICAL" Improvements to IED Detection

The urgency of improvised explosive device (IED) threat mitigation for deployed troops warrants an immediate and sweeping response, and an AFRL/Electronic Systems Center (ESC) program aptly hailed as RADICAL delivers just that. The chief goal of RADICAL—referenced more formally as the Remote-Controlled Improvised Explosive Device Detection Identification and Classification Algorithms effort—is to provide ground forces operating in urban and similarly complex terrain with real-time, accurate information concerning the presence, type, and location of IED-associated electronics.

Developed by Nokomis, Inc., with AFRL/ESC Small Business Innovation Research (SBIR) funding, RADICAL leverages the company's Advanced Electromagnetic Location of Electronic Devices (AELED) technology. This patented capability is specially designed to detect and identify electronic devices, with a concerted focus on IED triggering mechanisms. The AELED system is proven in its capacity to pinpoint commonly used IED electronics at distances exceeding 1 km. RADICAL enhances this existing capability via the addition of phenomenologically based plug-in modules for detection and geolocation. This updated approach, which incorporates tactically favorable arrays widely accepted throughout the Department of Defense, provides precise detection, identification, and location data for a given target. Users access this real-time information through an intuitive, easy-to-use graphical user interface (GUI).

Nokomis has transitioned its RADICAL technology into SBIR Phase II and Phase III contracts with the Defense Threat Reduction Agency, Navy, and Air Force, collectively satisfying three major service components in fielding technology for expertly detecting, identifying, locating, suppressing, and neutralizing electronic devices from range. The involved parties are currently working to coordinate the RADICAL integration aboard both small unmanned aerial vehicles and ground vehicles.

Further, RADICAL recently earned transition funding from AFRL's Commercialization Pilot Program, following stakeholder concurrence regarding an appropriate SBIR Technology Transition Plan (STTP). The agreed-upon STTP takes specific aim at strengthening—and accelerating the development of—RADICAL geolocation algorithms, which essentially shape the technology's capacity to pinpoint the location of electronic emitters. Such enhancements to geolocation functionality will enable users to localize multiple targets, account for different array configurations in order to accommodate changes in the array, analyze geolocation data from a moving platform, and employ the GUI to view target overlays on a map.

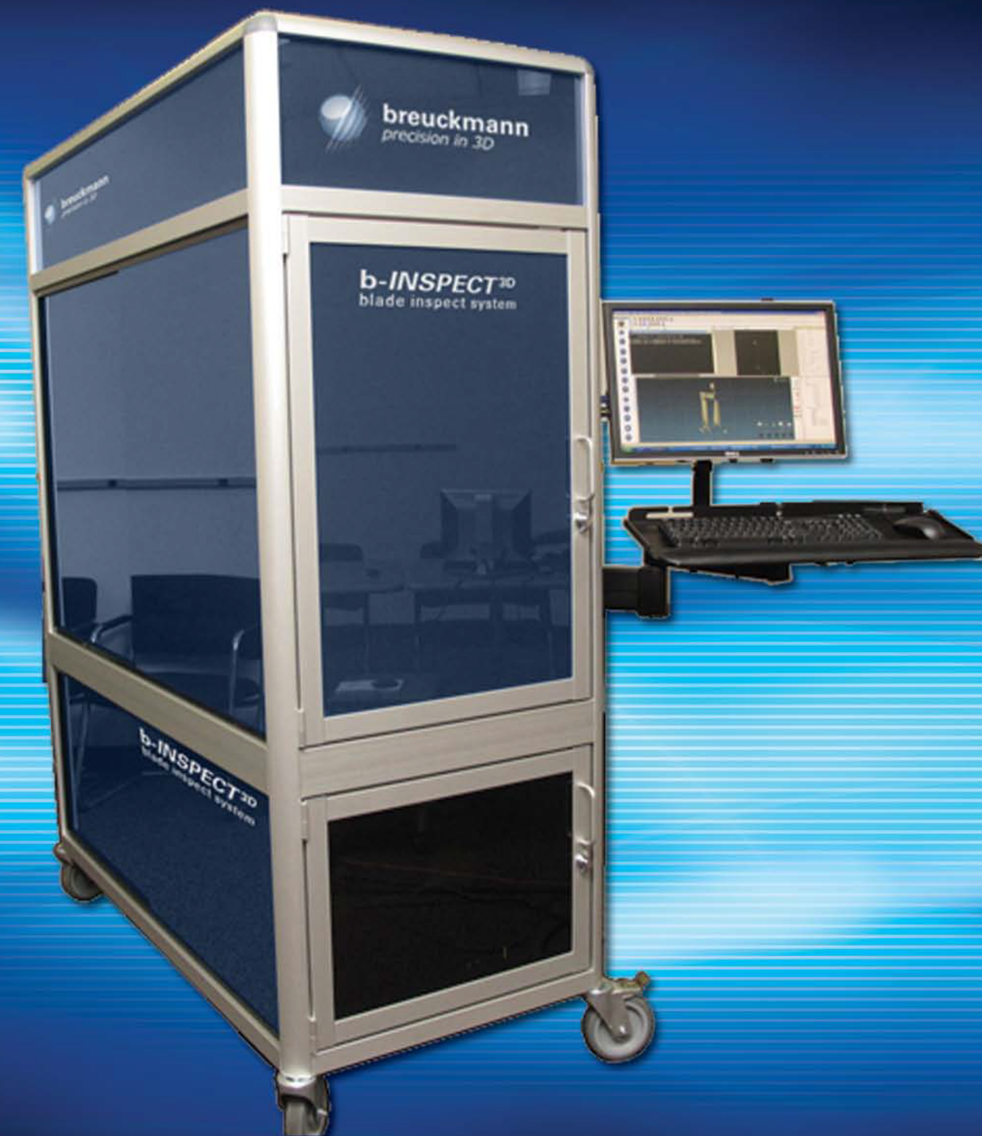
3DAI Foils Costly Engine Inspection

Seeking a more expedient approach to engine airfoil inspection, an Integrated Project Team (IPT) established an alternate methodology expected to cut substantial time (and consequently, cost) over current techniques, which are too slow for full-rate/surge production or efficient maintenance operations. The IPT—which included AFRL Manufacturing Technology (ManTech) engineers; Army Aviation and Missile Research, Development, and Engineering Center experts; airfoil casting suppliers; sensor suppliers; and three original equipment manufacturers—developed a Three-Dimensional Airfoil Inspection (3DAI) capability in order to demonstrate the type of high-speed data collection and analysis of complex airfoil geometry needed for achieving significant cycle-time savings.

Engines have hundreds of airfoils. Composed of cast alloys and various organic and ceramic matrix composites, each airfoil takes an average of 1 hr to inspect using current, Coordinate Measuring Machine (CMM) methods. Conversely, the 3DAI system expedites the inspection process by scanning the airfoil and creating an associated point cloud. The point cloud, which is developed from the inspection data, undergoes comparison to the CAD file of the part. Error maps representing the differences between the CAD dimension and the point cloud are then compared and used to identify part locations shown to be outside of tolerance bands. The overall aim of the 3DAI implementation is to accelerate—by means of a 90% reduction in airfoil inspection time—the rate at which weapons systems are fielded. Meeting this goal translates to decreasing the airfoil inspection period from 1 hr per airfoil to <6 min per airfoil. Thus far, the 3DAI system has achieved 2 to 4 min inspection times.

The cost avoidance projected for this reduction amounts to $26 million—a figure encompassing 1,500 afterburning turbine (fighter) engines rated for 29,000 lbs of thrust. Additional advantages afforded by the technology include reduced airflow variation (which could also enable decreases to total cooling flow), increased engine efficiency, lower fuel consumption, and potentially longer component service life due to better control of cooling at critical locations.

The 3DAI system progressed from a conceptual drawing to a working prototype in 17 months (April 2008 to September 2009). Ultimately, this positive outcome supports ManTech's Advanced Manufacturing Propulsion Initiative, which seeks to transform the Air Force propulsion supplier base in order to assure industrial capability and capacity in meeting production demands and to accelerate the transition of advanced technology. Among the 3DAI technology's potential implementation platforms are the T700, F135, and F136 engines.



AFRL engineers participated in an IPT effort to develop a 3-DAL system (pictured) for reducing the time and costs associated with engine airfoil inspection methods.

Materials engineers from AFRL's Air Force ACO developed this HAM.

Advanced Composites Office "HAMs" It Up

AFRL's Air Force Advanced Composites Office (ACO) transitioned to Ogden Air Logistics Center a hot air module (HAM) addressing problematic elevated-temperature bonded repairs, which are especially difficult for depot crews working in field conditions. Cumbersome and time-consuming, bonded repairs of this nature have traditionally required large curing systems, tedious manipulation of heat lamps and blankets, and about 9 hrs to complete. Such repairs are also prone to substantial bond-line errors. The ACO's HAM solution reduces the logistical footprint, cuts the lengthy cure time in half, and meanwhile resolves recognized bond quality issues.

While HAM technology is not altogether new—for example, Northrop Grumman's Portable Curing Hot Air System (PCHAS) has been in use for years—the newly transitioned unit offers significant improvement over current capability. First and foremost, it enables depot maintainers to perform elevated-temperature bonded repairs and noncontact curing in the field. Further, it is less expensive and smaller than the non-commercially-produced PCHAS (which carries a $1 million price tag and, at several hundred pounds, is about the size of a small trailer and must be towed behind a truck). Manufactured by Jet Solutions, LLC, the ACO-developed unit's commercial availability translates to better affordability. Likewise, the HAM innovation's smaller aspect (approximately 10% the PCHAS footprint) is better suited for field use.

AFRL's strategy for implementing its updated HAM design was to make it a commercial off-the-shelf (COTS) capability. Ultimately, it was Jet Solutions that built a production version of the improved technology, and the company has since worked closely with the ACO to ensure the resulting COTS unit's ongoing capacity to meet or exceed requirements. Illustrating the enhanced technology's effectiveness, depot repair crews used it to bond a machined titanium (Ti) doubler to the surface of a C-130's main wing plank, with positive results. The Ti doubler repair process uses a heat-activated epoxy adhesive that requires curing at 180°F to 250°F (+/- 5°F). The new HAM unit's capacity to adjust curing temperatures accordingly, with crews able to easily redirect the movement and intensity of hot air across (or directly onto) a given surface, enables a much more evenly heated—and thus greatly improved—bond-line. Having just undergone its first-ever operational implementation—in the depot repair of the C-130 wing plank—the HAM technology has successfully transitioned to the warfighter.

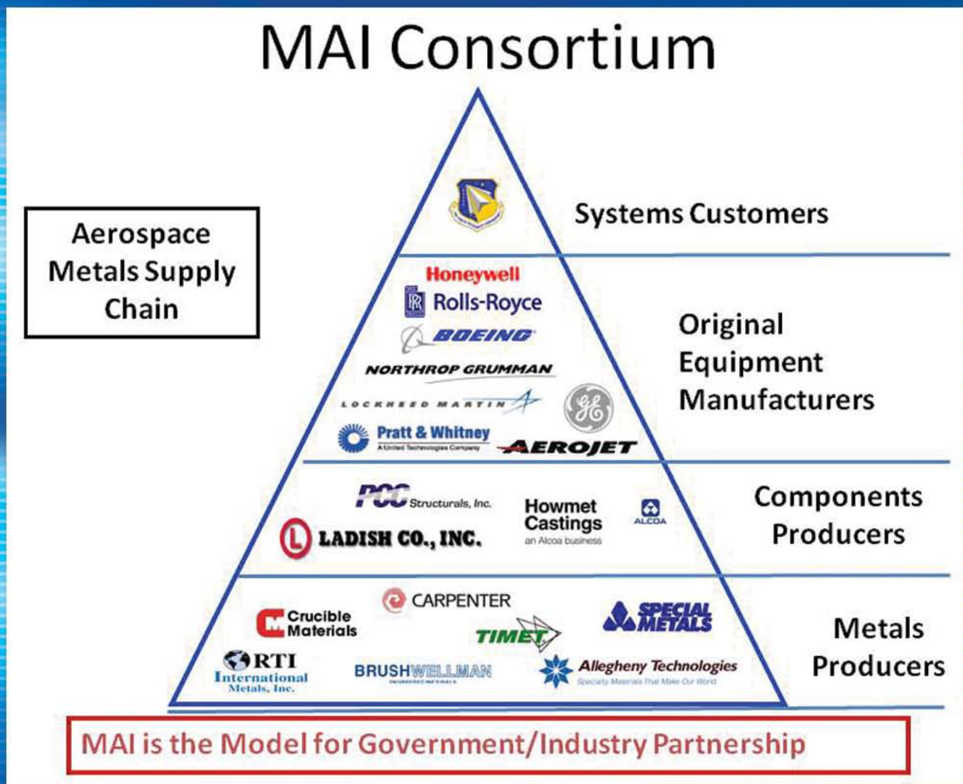
SiC Manufacturing Advances Aid Next-Generation Engine Technology

AFRL's Manufacturing Technology Division and GE Aviation are transitioning state-of-the-art technologies related to the improved manufacture of coated silicon carbide (SiC) fibers—which, as vital materials in the development and maturation of ceramic matrix composite (CMC) engine components, contribute to reduced cost and better performance for weapon systems. Specifically, the use of SiC-based CMCs for engine components lowers fuel costs by replacing metal alloys, a substitution that decreases weight and, in turn, improves speed and acceleration. Experts anticipate that the introduction of SiC CMCs into a single aerospace engine alone—the T700, used in the Apache, Blackhawk, Knighthawk, and other next-generation aircraft—will save 1 million gallons of fuel annually.

Current superalloy turbine engine components are heavy compared to CMCs. This excess weight negatively impacts engine fuel efficiency and prompts repeated repairs, contributing to higher life-cycle costs for aerospace systems. Reducing the weight of turbine engine vanes by replacing metal alloys with CMCs improves engine fuel economy as well as performance. Further, the improved durability of CMC components translates to less frequent maintenance and, consequently, lower life-cycle costs.

The AFRL/industry team's Ceramic Matrix Composite Manufacturing Initiative (a Defense-Wide Science and Technology–driven effort) involves both the conversion of a multistep batch process for coating fiber tows into a single-step process and the improvement of corresponding machine parameters and cycles. To date, project engineers have implemented a 100% increase in the coating run length with existing equipment. The implementation has increased coating capacity from 137 m to 275 m of fiber. With the resulting materials having undergone successful validation during CMC panel fabrication and mechanical property testing, the project's ultimate goal is a 550 m capability, with SiC prepreg system demonstration slated for later this year.

Pictured are turbine engine components that could benefit from in-line tow coating advances.



Graphically depicted structure of the MAI, an AFRL-managed consortium geared towards consolidating government/industry resources to reduce the costs and lead time associated with producing metallic aircraft components.

Metals Affordability Initiative: Technology Transition Through Collaboration

The AFRL-managed Metals Affordability Initiative (MAI)—a consortium dedicated to leveraging consolidated government/industry resources to reduce metallic aircraft component costs and accelerate component implementation—has thus far sparked the successful transfer of 50 technologies into 22 aerospace systems across the Air Force and Department of Defense, with 39 independent technologies transitioned directly to the warfighter. These key technology insertions have impacted the C-17, C-40, C-130, E-2, F-15, F-16, F/A-18, F-22, F-35, KC-135, P-8, V-22, Global Hawk, and Apache aircraft. They have likewise influenced the micro satellite, small-diameter bomb, Mars reconnaissance orbiter, and Orion spacecraft, as well as a variety of future combat systems. Bringing together competing companies that share the common goal of decreasing costs and time to market, the consortium comprises 16 original equipment manufacturers, component manufacturers, and metals producers—each of which is an important contributor in the aerospace supply chain and has achieved a tremendous record of technology transfer and cost-reduction impact.

Given that metals constitute nearly three-fourths of turbine engine components and two-thirds of a typical airframe's weight, their cost and performance have a significant effect on a wide array of defense systems. Since the MAI's 1999 inception, the government/industry consortium has worked to reduce the costs and improve the performance of metals and alloys, challenging conventional thinking and generating overall savings totaling more than \$500 million. Through this teaming of AFRL with representative aerospace metals and component suppliers—a large cross section including mills, forge and casting shops, airframe and systems integrators, and engine manufacturers—the military has not only reaped the technical benefits of experienced industrial specialists and experts, but meanwhile exposed a broad private-sector audience to a host of promising technology investment opportunities. The collaborative nature of the MAI has enabled an impressive list of technological successes, with government and industrial partners sharing a financial stake in technology development and actively engaging in unified technical oversight. Accordingly, each project tackled requires a focused technical plan, defined implementation targets and milestones, and a realistic and supportable business case. The shared risk—and reward—stimulates projects that are timely, feasible, and supported by the entire metals value stream.

Tech Transfer Pulls—and Pushes—Its Weight in Lab/Industry Partnering

Given that the Air Force (AF) recognizes industry partnerships as key to bridging capability gaps and mitigating risk, AFRL strives to exploit technology transfer to enhance such collaboration, an approach that brings dollars, resources, and time savings to AF programs and ultimately speeds product delivery to the warfighter. Whether used to "spin in" technology from the private sector or "spin out" the results of AFRL research to business, tech transfer opportunities are virtually endless, due primarily to the availability of various legal vehicles and numerous federal laboratories at which research spans a wide range of scientific disciplines.

Exemplifying the use of transfer mechanisms for acquiring needed technology is AFRL's effort to advance state-of-the-art warfighter readiness methods and techniques. Seeking a commercial partner that could bring complementary capabilities to the project, the lab teamed—under Cooperative Research and Development Agreement (CRADA), which opens AF test facilities and equipment to commercial clients who may otherwise lack access to specialized equipment—with range instrumentation and architectural software developer Cubic Defense Applications. The successful pairing was subsequently able to "spin in" the commercial technology needed for developing the air-ground systems interface needed for realizing a real-time, real-world training capability known as live-virtual-constructive (LVC) technology. The aim of the LVC system is to improve the quality and efficiency of training, not only for Joint Terminal Attack Controllers (AF troops operating within Army units to identify targets and coordinate close air support), but for fighter pilots and the Air Support Operations Center personnel who execute their respective battle plans.

Highlighting technology "spin out" is AFRL's involvement in a National Fallen Firefighters Foundation (NFFF) effort to gather data regarding the size and shape of firefighters. The purpose in collecting this information was to aid the formulation of industry guidelines for improved fit and function of firefighting safety equipment, clothing, and vehicles. NFFF commercial partner Total Contact, Inc., made use of resources at AFRL's Computerized Anthropometric Research and Design laboratory—via an existing CRADA between the AF and a private contractor— to obtain the desired statistics via lab-proffered technology assets. This particular study will eventually dovetail with a comprehensive, separately funded National Institute of Occupational Safety and Health (NIOSH) project to collect anthropometric data from ~1,000 firefighters nationwide, with AFRL sharing NFFF outcomes with NIOSH and perhaps brokering a formal AF/NIOSH collaboration.

An anthropometry specialist prepares a firefighter test subject (dressed in full turnout gear) for a three-dimensional scan at AFRL's Computerized Anthropometric Research and Design laboratory.

The DARPA–developed software includes a plug-and-play capability for incorporating updates.

ESP Adds New Dimension to Engine Health Prediction

AFRL's transition of a Defense Advanced Research Projects Agency (DARPA)-developed system that calculates turbine engine component damage and facilitates accurate predictions of future engine health will cut costs and improve operational readiness and safety. Newly transitioned to Tinker Air Force Base, Oklahoma, the Engine System Prognosis (ESP) system provides unique technology to help manage premature component replacement, which is enormously expensive for the Air Force (AF). DARPA's new capability remedies this problem by enabling component-specific checks of engine bearing, hot gas path component, fan/compressor blade, and turbine disk health. Though especially relevant for older engines, the system is nonetheless applicable to today's advanced engines as well.

Aircraft engines are one of the AF's major assets. As such, replacing/discarding their myriad components before they have actually expired constitutes a huge—and often unnecessary—cost, both in terms of resource usage (i.e., time) and in dollars spent towards the purchase of new parts. The capacity for aircraft maintainers to correctly, confidently predict engine component life will greatly reduce these costs—and with no sacrifice either to personnel well-being or to mission preparedness.

The ESP architecture includes four software modules: fan and compressor airfoil high-cycle fatigue (HCF) lifing, disk life-predictive methodologies, bearing damage sensing and lifing, and hot gas path component life prediction. As an example of the system's efficiency, the module for fan and compressor airfoil HCF lifing leverages information unique to the physical relationship between airfoil damage state and airfoil response; by coupling this case-specific data with a built-in damage accumulation mechanism, the technology enables safe engine operation in the presence of damage well above (i.e., greater than 50 times) the levels currently allowable.

DARPA's development effort focused on physics-based approaches to analyzing and predicting material failure-causing defects in the F100 and F110 engines. Having ultimately delivered to the AF an ESP unit at Technology Readiness Level 6, the team has produced a novel capability officially designated as achieving an advanced state of readiness.

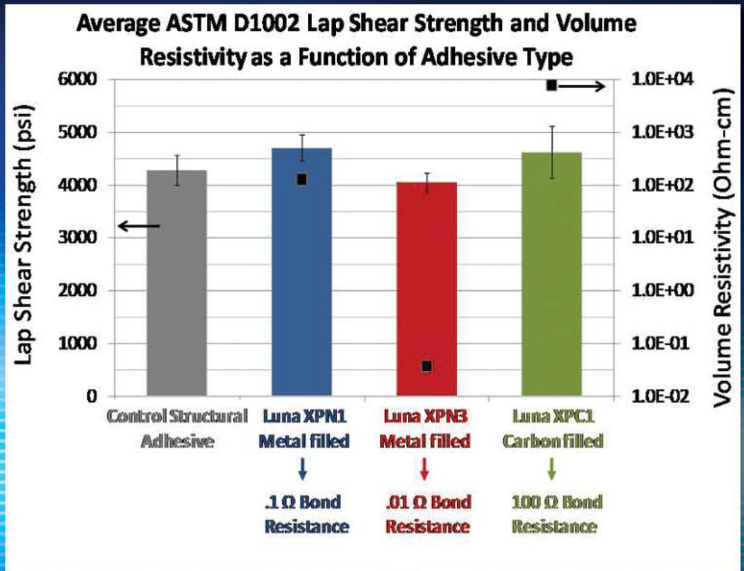
High-Strength, Conductive Adhesives a Sticky Proposition

AFRL Small Business Innovation Research (SBIR) resourcefulness is behind new adhesives promising increased performance and substantial cost savings for a wide variety of Air Force (AF) and Department of Defense (DoD) air and space platforms. Specifically, the SBIR Phase II work—performed by Luna Innovations—produced high-strength aerospace adhesives supplying continuous electrical conductivity and thus addressing the military's need for bonding agents that are not only strong, but also able to mitigate electrostatic discharge (ESD) on aircraft/spacecraft surfaces, facilitate electromagnetic interference (EMI) shielding, and protect craft from lightning strikes (LS). Applications demanding a combination of high-strength structural joining and increased electrical conductivity will benefit from leveraging the new adhesives as bond and/or filler materials. Further, by reducing—and, in some cases, eliminating—the need to outfit structures with costly electrical materials in addition to complex ESD, EMI, and LS mitigation mechanisms, the single-package technology could save the AF and DoD millions of dollars annually.

The capacity to maintain continuous electrical conductivity across an aircraft/spacecraft surface is crucial for meeting the comprehensive electrical and mechanical requirements of the particular system. At joints, gaps, and bolt holes, this is difficult at best, with current solutions entailing both an electrical bridging component (e.g., an adhesive or wire mesh) and a structural adhesive. Unfortunately, these components result in high costs, extra weight, and configuration complexity. To address these issues, Luna adopted a novel approach—one involving the careful selection and dispersion of conductive fillers within high-performance adhesive resins. This process creates conductive adhesives with pot life (working life), cure time, and application and mechanical properties similar to those of the products presently used by the military, commercial aircraft manufacturers, and maintainers.

The adhesives have undergone characterization for determining their performance properties, including bond resistance, volume resistivity, shielding effectiveness, lap shear strength, out-gassing characteristics, and other metrics that serve to define end-use applications. Results indicate that Luna's adhesives have tailorable mechanical and electrical properties; for example, the company has developed adhesive formulations exhibiting lap shear strengths of 4,500 lbs/in^2 and electrical resistance of $<0.1\ \Omega$ across the bond. This tailorability promotes increased design flexibility and assembly speed, adding to already-noted advantages in terms of enhanced system performance and reduced costs, weight, and complexity.

Air Force SBIR/STTR



Pictureed (top) is data showing that the adhesive compares favorably to commercial products. Pictured (bottom) are Luna products.

Production of high-rate precision polyimide prepreg material (pictured top); MVK-14 FreeForm™ polyimide autoclave molded parts (pictured bottom)

Lab Collaborates With NCAMP on Material Properties Database

AFRL materials engineers are collaborating with researchers from the National Center for Advanced Materials Performance (NCAMP) to generate a material properties and allowables database as part of an effort to qualify a high-temperature composite material for use in engine and airframe applications. The database addresses the growing demand for affordable, lightweight, and more environmentally friendly MVK-14 FreeForm™ high-temperature polyimide composite material. It also provides a synergistic tool that appeals to military and commercial customers interested in using the material for airframe structure or propulsion applications.

Both AFRL and NCAMP materials experts believe that polyimide composite materials offer a desirable alternative to the current titanium and bismaleimide composite materials found in many high-temperature aerospace parts. Polyimide composites, which can operate in temperatures up to 700°F, provide significant weight, cost, and environmental advantages. They may also eliminate the need for heavy thermal insulation or protective coatings and, further, will reduce maintenance costs in some applications. Aircraft manufacturers will be able to use the NCAMP database, which contains primarily carbon-fiber-reinforced epoxy and bismaleimide composites, to design parts and then subcontract parts fabrication to any of the 13 companies that have participated in the qualification process and/or have shown process equivalency.

Many aerospace manufacturers have expressed interest in using polyimide composites to replace titanium, steel, or INCONEL® parts in order to reduce cost and weight in aerospace structural applications. However, designers need a polyimide material properties database to perform trade-study comparisons of various materials. The material property data acquisition and qualification program defined by representatives from the Air Force (AF), Naval Air Systems (NAVAIR) Command, National Aeronautics and Space Administration, Federal Aviation Administration, and NCAMP Manufacturers Advisory Board generates the basic material information needed both for the comparison process and for establishing material property control. Eighteen aerospace companies and NAVAIR assisted the AF in determining the best polyimide composite candidate available, and MVK-14 FreeForm™ emerged as an aerospace industry favorite. The product family is based on Maverick Corporation's MVK-14, a safe, noncarcinogenic polyimide resin system formulated and patented in 2000 and features enhanced performance attributes enabled by GE Aviation's FreeForm™ technology. This program marks the first time government funding has been offered to create a collection of databases intended for both the Department of Defense and commercial aerospace applications.

AWARDS & RECOGNITION

Lab Deepens Commitment to Latin American Science Community

The Southern Office of Aerospace Research and Development (SOARD), an international detachment of AFRL, recently kicked off its first basic research initiative to discover talented researchers—and create meaningful partnerships—in the Latin American science community. Demonstrating the lab's engagement in and commitment to such international research collaborations, this program will generate opportunities for working together and thus foster new ideas with profound impact on the Air Force (AF) and the world.

SOARD coordinated the kickoff meeting with the Centro de Investigación en Materiales Avanzados (CIMAV), Mexico's Center for Research in Advanced Materials. The Consejo Nacional de Ciencia y Tecnología (CONACyT), the National Council of Science and Technology—Mexico's equivalent to the US National Science Foundation—also played a role, providing essential authorization and funding support.

During the event, teams presented their basic research proposals to a Mexican-US panel, led by SOARD, CIMAV, and CONACyT representatives and comprising program managers from AFRL and the Office of Naval Research, all of whom provided valuable evaluations of each submission. The proposals selected during this process will benefit the AF in areas such as organic materials chemistry, reconfigurable materials for cellular electronic and photonic systems, and surface and interfacial science.

For each selected proposal, the panel awarded a research grant of $500,000 a year for 3 years towards ongoing work in the respective basic research area. Additionally, SOARD will invite the sponsored researchers to attend ongoing AFRL program reviews and poster sessions in order to enhance one-on-one interactions, establish new contacts, and impart suggestions for future research efforts.

AFRL's SOARD recently kicked off its first basic research initiative to discover talented researchers—and create meaningful partnerships—in the Latin American science community.

Mr. Thomas Wells (pictured left), 711th HPW director, presents the 2009 Harry G. Armstrong Scientific Excellence Award to Mr. Brian Simpson, engineering research psychologist with the Human Effectiveness Directorate.

Scientific Excellence Award Goes to AFRL Psychologist

Mr. Brian Simpson, an engineering research psychologist with the AFRL 711th Human Performance Wing's (711 HPW) Human Effectiveness Directorate, Warfighter Interface Division, Battlespace Acoustics Branch, received the 2009 Harry G. Armstrong Scientific Excellence Award at 711 HPW's annual awards banquet, held January 2010 at Wright-Patterson Air Force Base (WPAFB), Ohio.

The Armstrong Award, which commemorates Major General Armstrong's pioneering career in aerospace medicine research at WPAFB, represents an annual honor presented in recognition of 711 HPW's most significant scientific or technical accomplishment.

Mr. Simpson's selection is based on his innovative work in battlespace acoustics research, including service in roles as both principal investigator and team lead for the analysis and processing of complex auditory scenes.

Dr. Siva Banda Earns Distinguished Senior Professional Honors

Dr. Siva S. Banda, director of the US Air Force Center of Excellence in Control Science at AFRL, earned the Presidential Rank Award of Distinguished Senior Professional. Secretary of the Air Force Michael Donley presented Dr. Banda with the prestigious award during an April 30, 2010, ceremony held at the auditorium of the Women's Memorial at Arlington National Cemetery. During his nearly 30-year career as an AFRL scientist, Dr. Banda has led many groundbreaking research efforts. He assembled the Center of Excellence in Control Science, a world-class team of acadamic, commercial, and government experts focused on Air Force–critical control science challenges. Comprising more than 70 scientists, engineers, and researchers, this team has devised technologies for tailless flight, space access, unmanned air vehicles (UAV), and countless other military applications critical to twenty-first century capabilities.

Recognizing the benefits of using unmanned aircraft in the urban battlefield, Dr. Banda crafted and executed a research and development strategy for enhanced autonomous and cooperative control of UAVs. Additionally, he led an international joint development team that developed control strategies for micro air vehicles in urban operations. Dr. Banda's research has had far-reaching impact, both nationally and internationally. The results of his work have application to a number of current Army, Air Force, and Marine Corps small UAV operations. Additionally, his research was applied during the 2007 and 2009 occasions of the US-Australia Talisman Saber Exercise, the largest joint warfighting exercise in the Pacific and a key demonstration showcasing UAV technologies.

Distinguished Senior Professional is the highest annual award for senior-level/senior technical career professionals. It is bestowed upon federal executives who have demonstrated a consistent level of extraordinary achievement.

Secretary of the Air Force Michael Donley (pictured left) presents AFRL's Dr. Siva Banda with the Presidential Rank Award of Distinguished Senior Professional. Air Force Chief of Staff General Norton Schwartz (pictured right) also attended the ceremony.

Dr. Winston "Wink" Bennett, Jr. (top left), Dr. Frank O. Clark (top middle), Mr. Richard L. McKinley (top right), Dr. Fred Schauer (bottom left), Dr. Boris Tomasic (bottom middle), and Dr. Richard A. Vaia (bottom right)

AFRL 2010 Fellows Award Winners

Dr. Winston "Wink" Bennett, Jr., of the Human Effectiveness Directorate, has made significant contributions to Air Force (AF) methodology for shaping the knowledge, skills, and developmental experiences necessary for meeting recurrent training requirements/standards and achieving combat mission readiness and success.

Dr. Frank O. Clark, of the Space Vehicles Directorate, provides managerial, strategic planning, and scientific expertise in the missile warning arena. His latest, patent-pending research into hypertemporal intelligence is yielding interesting new forms of intelligence and also promises future applicability in the detection of underground activity.

Mr. Richard L. McKinley, of the Human Effectiveness Directorate, is an expert in human-centered acoustic research, including spatial hearing, speech communication, hearing protection, and noise measurement and exposure. His developments in active noise reduction, three-dimensional audio displays, speech communication electronic warfare, and aircraft noise measurement and modeling have positively impacted not only AF operational preeminence, but the quality of life worldwide.

Dr. Fred Schauer, of the Propulsion Directorate, provides key insights and expertise in the pursuit of detonation-driven hybrid turbine breakthroughs, supercritical endothermic regenerative fuel cooling technology, and direct initiation methodologies for practical fuels.

Dr. Boris Tomasic, of the Sensors Directorate, provides expertise in antenna theory, design, and computational electromagnetics. His many key projects have addressed the AF sensor needs of present and future ground, air, and space systems.

Dr. Richard A. Vaia, of the Materials and Manufacturing Directorate, is the foremost DoD proponent for aerospace nanomaterials development. He has led cross-directorate nanoscience and technology (NST) activities and created forums for accelerating NST collaboration between industry, academia, and the DoD.

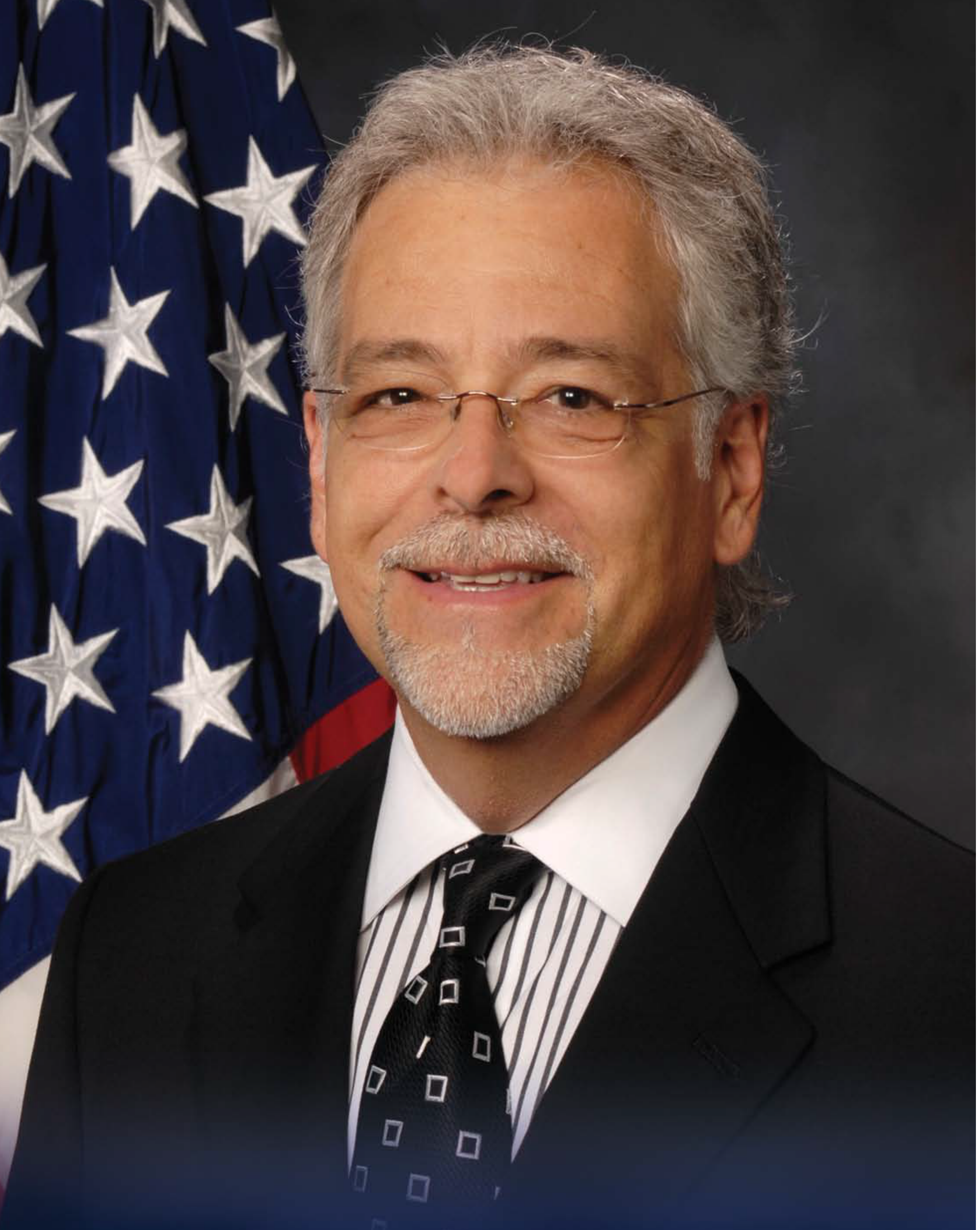
Team Honor "STEMs" From Flash-Bang Research

As part of the Department of Defense effort to outfit warfighters with nonlethal escalation-of-force capabilities, an Air Force (AF) team studying the human effects of the Improved Flash-Bang Grenade (IFBG) earned the AF 2009 Science, Technology, Engineering, and Mathematics (STEM) Award for Outstanding Scientist Team. STEM awards recognize science, engineering, and technical management excellence and achievement throughout the AF. This honor specifically recognizes the IFBG team for its contributions towards the development of a safer and more effective flash-bang grenade. According to the award citation, the team determined the human effects necessary for increasing mission effectiveness by analyzing flash-bang grenade injury data, writing software to analyze flash effects, and determining sound exposure limits. The research resulted in critical design and performance specifications for IFBG prototypes meeting US military needs.

Creating a loud bang and a large, bright flash to temporarily incapacitate targeted individuals, the IFBG technology—which lengthens the period of incapacitation compared to earlier versions of the device—not only improves safety for the user and any noncombatants in the target area, but also reduces environmental impacts. Currently in the engineering and manufacturing development phase of the acquisition process, the IFBG will soon supply US forces with a nonlethal capability better supporting missions such as hostage rescue, room clearing, and various operations in complex urban terrain.

The 12-member, Joint Nonlethal Weapons Program–sponsored IFBG team includes AFRL military, government, and contractor personnel. Through its human effects research, this team has led the way for improved grenade performance and safety, increasing the individual warfighter's capacity to conduct the full spectrum of military operations.

Several members of the IFBG team accept the AF 2009 STEM award for Outstanding Scientist Team during the STEM awards ceremony.



In addition to being a Fellow of AFRL and SPIE, Dr. James G. Grote now holds Fellow status in the OSA and the EOS

Optical Societies Honor AFRL Engineer

Dr. James G. Grote, a principal electronics research engineer at AFRL's Materials and Manufacturing Directorate, earned Fellow status both from the Optical Society of America (OSA) and from the European Optical Society (EOS), where he also now holds the distinction as being the first North American member to attain the esteemed standing. Dr. Grote's selection for this honor by two different prestigious organizations is a tribute to his outstanding individual achievement and dedication as an acknowledged international leader in organic and inorganic nonlinear electro-optical (EO) sensor materials and devices, optical interconnects, optical lithography, and deoxyribonucleic acid (DNA)-based materials and devices.

OSA's mission is to promote optics and photonics knowledge—its generation, application, archival, and worldwide dissemination. Similarly, EOS strives not only to contribute to progress in optics, optoelectronics, and related sciences, but also to foster international application of these sciences and facilitate cooperation among interested parties. The goal of both organizations lies in making practical use of research results and supporting industrial exploitation of optics technology. While OSA has more than 15,000 corporate, individual, and student members worldwide (with 55% from North America), EOS comprises more than 5,000 societal, corporate, individual, associate, and student members (1.27% of which are North American).

Reserved for distinguished members, the title of Fellow is the highest membership category conferred by either society and, consequently, designates no more than 10% and 2% of OSA and EOS members, respectively. For both societies, successful Fellow nominees have made outstanding research contributions to optics and photonics through published papers, books, conference presentations, patents, or other published material; have served the optics and photonics community by teaching or training, industrial leadership, or service as an editor, conference organizer, or other professional service; and have otherwise made a special contribution to the society.

Already a Fellow of AFRL and SPIE (the International Society for Optical Engineering), Dr. Grote has played a part in advancing a host of key technologies from fledgling research through international recognition, along the way spurring seminal joint publications and technology transitions. First joining AFRL in 1998, he performed in-house research of nonlinear optic polymer-based EO materials and devices, concentrating on the optimization of device performance via conductive polymer claddings. His conductive cladding technology ultimately achieved world-record lows in terms of device operating voltages and has since been adopted for widespread use throughout academia, government, and industry.

Dr. Grote's current research focus involves DNA-based bio-organic materials and devices.

Dr. Datta V. Gaitonde Earns 2010 AIAA Thermophysics Award

Dr. Datta V. Gaitonde, of the AFRL Air Vehicles Directorate, earned the 2010 American Institute of Aeronautics and Astronautics (AIAA) Thermophysics Award. The AIAA presents the award to individuals whose outstanding contributions to the science of thermophysics significantly advance the understanding of heat transfer: its properties, applications, and environmental effects. The AIAA recognized Dr. Gaitonde for his technical expertise and innovation; leadership within the international thermophysics community; and commitment to the development of researchers across government, industry, and academia.

Dr. Gaitonde's career has been characterized by remarkable advancements in the study of phenomena arising in hypersonic systems. Research of flow separation in hypersonic inlets and the manner in which it affects engine performance has suffered from inaccurate conclusions derived from two-dimensional models. Dr. Gaitonde resolved these problems by successfully simulating complete three-dimensional airflow on advanced supercomputers. He then used these computed results to propose and verify innovative models for the complex physics encountered by aircraft flying at hypersonic speeds, typically defined as Mach 5 and above.

Dr. Gaitonde serves as a technical leader and consultant for many organizations, both within and outside AFRL. He is a consultant on Defense Advanced Research Projects Agency and Air Force Office of Scientific Research programs and, further, is a member of the National Hypersonic Foundational Research Panel. He is the lead Department of Defense computational fluid dynamics consultant for international programs with Germany, as well as for the Hypersonic International Flight Research and Experimentation flight test program with Australia

Dr. Datta Gaitonde (right) receives his award at the June 29 AIAA Awards Luncheon in Chicago.

First Lieutenant Sean R. Majo, of the AFRL Sensors Directorate, won the Air Force Research and Development Award for 2009.

Air Force Research and Development Award Goes to AFRL Lieutenant

First Lieutenant Sean R. Majo, of the AFRL Sensors Directorate, won the Air Force Research and Development Award for 2009. He accepted the honor from the Vice Chief of Staff during a presentation ceremony conducted at the US Air Force Academy in September 2009.

The award recognizes Lt Majo's oversight of $3 million in programs geared towards developing radar and intelligence sensor technologies for small unmanned systems and counter improvised explosive device (IED) operations. As part of this focus, he developed and demonstrated a technique for detecting IED parts during their assembly, and the results of this critical work are presently assisting deployed warfighters. In addition, Lt Majo established national measurement standards for parametric radar systems. He worked jointly with the Army to create signature measurement techniques that ultimately increased detectable bandwidth and signal levels, improving signature detection levels up to 200%. Traceable standards enable quality improvements and make the measurement process transparent to the user. The intelligence and operational communities are now using Lt Majo's method Department of Defense–wide.

Lt Majo also conceived and initiated a program for investigating a new phenomenology in packaged electronic devices. He theorized and subsequently proved the feasibility that packaged electronic components, in the presence of electromagnetic radiation, will radiate distinct signatures. This research activity earned approval for a Small Business Innovation Research topic focused on advancing Lt Majo's preliminary efforts in this area.

Title III Nets Honors for High-Temperature Superconducting Advances

Having not long ago finished a 5-year effort to establish commercial production capabilities for yttrium barium copper oxide (YBCO)-coated high-temperature superconductor (HTS) wire—a technology that will significantly increase device energy efficiency for several military and industrial applications—a team led by AFRL Manufacturing Technology (ManTech) engineers recently earned the 2010 Federal Laboratory Consortium Technology Transfer Interagency Partnership Award for its work. The Defense Production Act Title III program involved collaboration with AFRL propulsion experts, as well as researchers from the Department of Energy and the Naval Research Lab. Also leveraged were the unique manufacturing capabilities of two commercial partners (American Superconductor and SuperPower, Inc.) in achieving program goals, which involved product performance metrics addressing conductor length; critical current; engineering current density; production capacity; and business metrics for long-term viability such as sales, production capacity, and cost.

The advantages generated through the YBCO HTS work incentivized both companies to make significant leaps in their respective production processes. For example, prior to realizing these improvements, each company achieved typical conductor lengths of just 10-20 m per production run. With the effort now concluded, both are producing YBCO-coated HTS wire that is 100 times longer and has over 5 times the electric current carrying capacity at operating temperatures. This translates into hundreds of kilometers, rather than simply meters, of production capacity—a capability that did not exist before program-based enhancements were implemented. Further, by accelerating the transition of this technology, the ManTech-led endeavor has made the benefits of YBCO-coated HTS wire available to the military and commercial sector 5-7 years earlier than might otherwise have been feasible.

The AFRL team members receiving the award include Dr. Paul Barnes, Mr. Ted Finnessy, Dr. Charles Oberly, and Mr. Tim Peterson.

An AFRL ManTech–led program effort earned the 2010 Federal Laboratory Consortium Technology Transfer Interagency Partnership Award for its advances in YBCO–coated HTS wire.

AFRL's Dr. Robinson Pino

Scientist Garners Distinguished Lecturer Standing

Dr. Robinson Pino, of the AFRL Information Directorate's Advanced Computing Division, recently earned approval to serve as a Distinguished Lecturer for the Institute of Electrical and Electronics Engineers (IEEE) Electron Devices Society. IEEE Distinguished Lecturers are engineering professionals who help lead their respective fields in new technical developments that shape the global community. They are specialists in their given IEEE society's field of interest and, further, travel to various technical and regional groups to lecture at relevant events.

Having joined IBM in 2005 and AFRL in 2009, Dr. Pino has for the past several years given lectures on the physics of semiconductors, covering diverse topics ranging from III-V compound semiconductors and device modeling and simulation to optoelectronics and memristor devices. Always well-received talks noted for their educational and practical scientific value, Dr. Pino's lectures—and the deliberately chosen language thereof—are accessible to experts spanning a broad range of disciplines. Consequently, Dr. Pino's days at AFRL are an extension of his time at IBM, at least with respect to his ongoing fielding of frequent requests to deliver national and international technical lectures and invited talks. It is for this reason that senior technical leaders of the IBM technology council nominated Dr. Pino for IEEE Electron Device Society Distinguished Lecturer status.

DIVERSITY

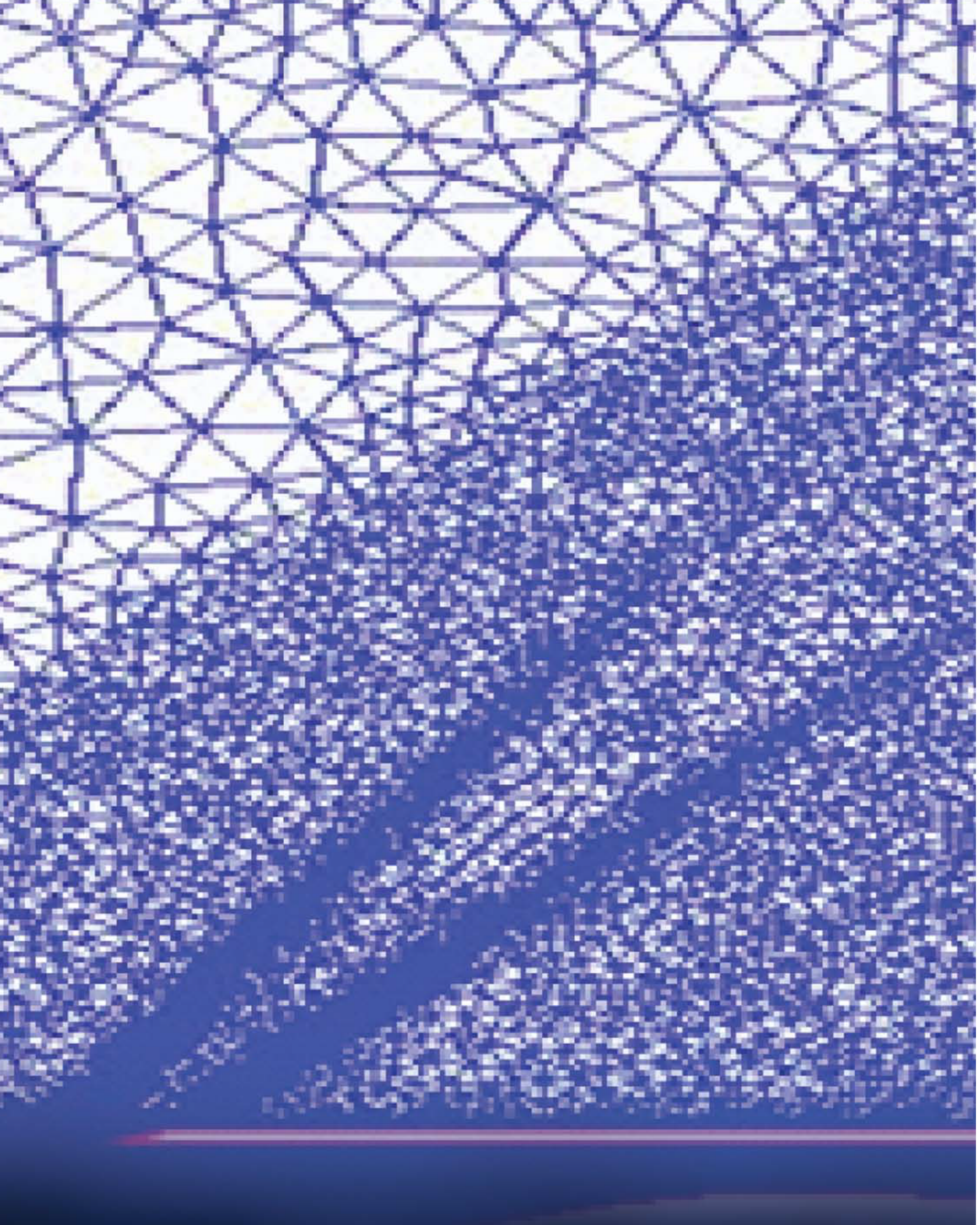
STEM Puts Students in the Driver's "SEAT"

A cross-directorate collaboration of scientists and engineers (S&E) is engaging with Dayton, Ohio, high school students as part of a Science, Technology, Engineering, and Mathematics (STEM) endeavor managed by Noble Solutions and sponsored locally by AFRL. As the program name implies, STEM seeks to stimulate student interest in relevant subjects by involving them in real-world fundamental research. This particular project—Students Exploring Advanced Technologies (SEAT)—unites AFRL S&Es with area Dayton Public Schools (DPS) students to that end.

The AFRL cohort's adopted strategy calls upon the SEAT student researchers to leverage the Science Fair process—namely, the inquiry-based research method—which, given that DPS students must participate in Science Fair activities at local (and, as applicable, regional, state, and international) levels, should be familiar to them.

Accordingly, the multidisciplinary lab team's "home" directorates sponsor the activities of a Remote-/Radio-Controlled Aircraft Team, a Rocket Team, and a Robotics Team, an approach that affords participating DPS students relevant opportunities to experience real-world applications of learned STEM concepts. With the specific SEAT teams helping students explore, reinforce, and elaborate upon those respective concepts, the partnership takes learning well beyond the classroom and into the realm of hands-on personal enrichment and potential STEM career pursuits of the future.

Students fly a remote-control aircraft, launch a rocket, and attend a robot competition. As the bar chart indicates, the number of DPS Science Fair projects jumped from 0 to >60 in 7 years. Although not shown here, the district's progress from Building Science Fair to State Science Day has increased 300%.



View of the finite element mesh with triangular elements grid created via unstructured Delaunay triangulation mesh

Multiobjective Optimization Betters Propulsion Design

Optimally performing propulsion systems require that the competing needs (i.e., individual design parameters) of various components be considered holistically—enter AFRL research partner Prairie View A&M University (PVA&MU) and its successful demonstration of a solution that does just that. Known as multiobjective optimization, the approach merges elements of computational fluid dynamics (CFD) and surrogate modeling techniques to achieve desired functional results; it also reduces the sizeable computing costs of optimizing complex propulsion designs via traditional means.

With the goal of optimizing a supersonic inlet for demonstration purposes, PVA&MU's Dr. Ziaul Huque employed Pareto-Optimal Front, a method involving design-variable surfaces wherein the optimal design can be chosen based on the importance of multiple objective functions. In this case, Dr. Huque selected a response-surface-based methodology, prompting CFD simulations of various inlet designs based on a matrix of variables/parameters for developing the response surface. This optimization effort is easily extended to follow-up activities in order to include more design variables and objective functions (e.g., nozzle and combustor).

Also completed was a study of the inlet's performance trends, with mass flow rate through the inlet and entropy gain used as the objective functions. Angle of attack, axial length from the ramp tip to the cowl tip, and inlet Mach number were the three variables used for the CFD simulations, with inlet dynamic pressure kept constant at 1500 psf. Execution of the inlet CFD simulations occurred via CHEM, a general-purpose, multidimensional, multispecies, viscous chemistry solver built upon a rules-based specification system. The standard, least square method generates response surface by the statistical code JMP. The elitist NGSA [Non-Dominated-Sorting Genetic Algorithm] II determined the Pareto-optimal solution. Each Pareto-optimal solution represents a different compromise between design objectives. This gives the designer a choice to select a design compromise that best suits the requirements from a set of optimal solutions.

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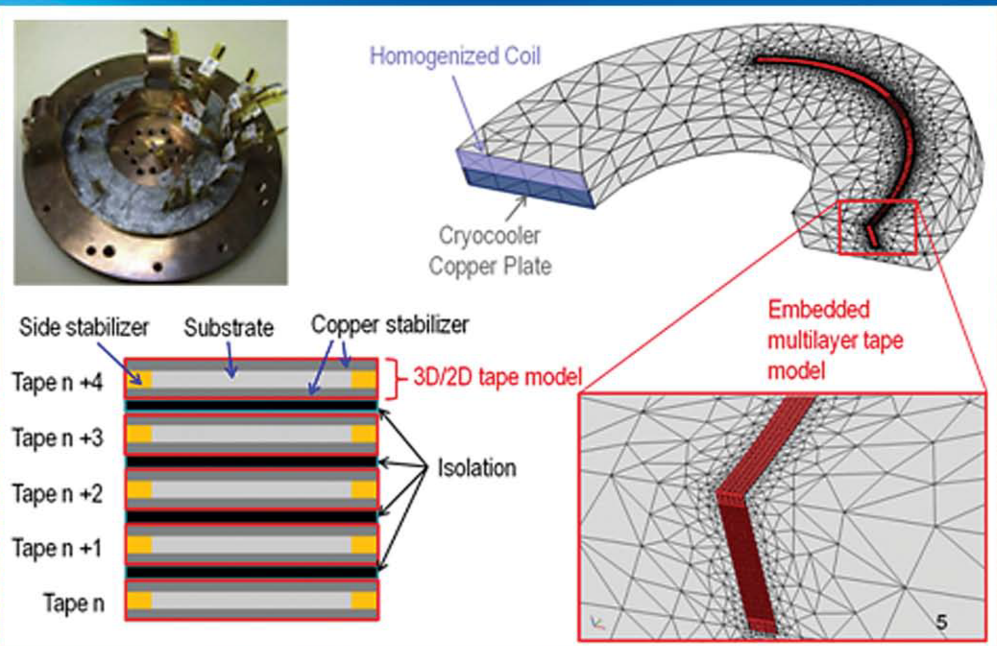
MUPI Conference Reception Features Keynote on AFRL Opportunities

Mr. Ed Lee, who manages AFRL's Historically Black Colleges and Universities/Minority Institutions (HBCU/MI) program, was recently the featured speaker at the opening reception for the 2010 Member University Professional Institute (MUPI) Conference: "HBCUs and Beyond, Cultivating Leaders for the Global Marketplace." Tennessee State University (TSU) hosted the MUPI event, which took place at Nashville's Gaylord Opryland Hotel & Convention Center. Mr. Lee addressed an audience comprising TSU students and faculty and Thurgood Marshall College Fund (TMCF) staff members in his talk, entitled "Establishing Student-College Relationships at AFRL Facilities."

Mr. Lee has supported this important event for the past 2 years, primarily through his delivery of presentations highlighting AFRL research opportunities for faculty, as well as employment and scholarship information for students. His goal is to foster AFRL's relationship with TMCF and the 47 public HBCUs/MIs that the organization represents. Illustrating this mutually beneficial rapport is an exchange wherein AFRL's issuance of a grant to TMCF subsequently enabled the lab to secure 15 summer intern slots. While on hand for MUPI Conference activities, Mr. Lee also visited the TSU campus and observed firsthand the university's new Biotechnology Center, a resource made possible by Defense Research and Engineering funding, support again provided through AFRL.

Mr. Ed Lee, AFRL HBCU/MI program manager, recently delivered a presentation on AFRL opportunities to 2010 MUPI Conference-goers.



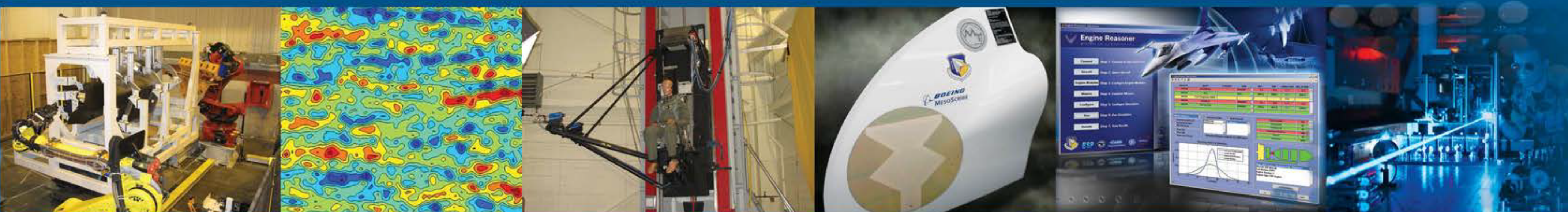
A diverse effort involving lab funding and FAMU research produced a hybrid finite element model for analyzing quench dynamics in superconducting coils.

Research Quenches Need for Mixed-Dimensional Coil Modeling

Motivated by the need for more in-depth study of yttrium barium copper oxide (YBCO)-coated superconducting coil—a technology of substantial value to compact, lightweight power applications of great interest to the Air Force—Florida A&M University (FAMU) researchers created a hybrid, finite element model of conducting coil (i.e., conductor) quench dynamics. Based on a mixed-dimensional tape model, the new technique enables a given conductor's full, three-dimensional (3-D) representation to be replaced with an abridged, two-dimensional (2-D) version, providing high-fidelity results and reduced computational requirements compared to commercial software approaches for modeling 3-D quench propagation in superconducting coils.

Maintaining functionality at temperatures approaching 77 K, YBCO-coated tapes are among the most promising high-temperature superconducting (HTS) wraps, enabling development of advanced conductors, coils, and motors/generators. However, one factor limiting the widespread application of this technology is the poorly understood behavior of the YBCO-coated conductor under a quench event, when it loses its HTS capability. While YBCO's inherently low thermal diffusivity inhibits a quench from spreading quickly enough throughout the conductor to prevent a failure, a detailed finite element analysis of configurations that could aid propagation velocity would preempt this scenario. Unfortunately, such analysis has heretofore proven difficult because of the coated conductor's large aspect ratios (micron's thickness to millimeter's width).

The FAMU research exploits the fact that a 2-D representation of the conductor—one incorporating its detailed physical interfaces and behavior—is easily derived from 3-D modeling processes and, further, enables associated analysis that is not only faster (about 8 times) but less resource intensive (about 1/3 the finite elements used). Using this technique, the FAMU researchers have been able to predict the quench behavior observable in existing (in-development) coils. Already reported in the Institute of Electrical and Electronics Engineers' *IEEE Transactions on Applied Superconductivity* publication (Volume 19, Issue 3, Part 2), these work results were also part of proceedings at the 2010 Applied Superconductivity Conference.



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